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SOVIET SOIL SCIENCE

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OF POCHVOVEDENIYE

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DEVELOPMENT OF SOCIALIST AGRICULTURE AND PROBLEMS OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY DURING THE NEXT SEVEN YEARS

The published thesis of Comrade Nikita S. Khrushchev's speech at the 21st Congress of the Communist Party of the Soviet Union on the plan for expanding the national economy of the USSR from 1959-1965 gives a magnificent picture of the eventual growth of the industry, agriculture, and culture of our country. The Soviet Union is entering a new period in its development — a period of intensified building of Communist society. In the next few years a gigantic economic construction program for the material and technical foundation of Communism is to be carried out. The great historic task of overtaking and outstripping the most advanced capitalist countries in per capita production of goods is to be completed at an unprecedentedly rapid tempo.

The measures taken in recent years by the Party and the government to improve the organization of agriculture and to achieve increased production have met with great success. In 1958 an unprecedentedly large harvest was gathered in the Soviet Union. Many republics and regions fulfilled the plan for the production of grain and industrial crops early and by a large margin. The figures set for agriculture have in view a huge new rise in production.

The chief task of agriculture in the next seven years is to raise production to meet the people's requirements for high quality basic food products and industry's needs for raw materials.

One of the main tasks of agriculture in the next seven years is "to improve the utilization of land as the basic means of agricultural production "with the object of raising the yields of all crops. As indicated in Premier Khrushchev's thesis, increasing the grain production "will be the chief line of agricultural development in the future as well." The plan proposes an annual yield of 10 to 11 billion pounds by the end of the seven year period. Raw cotton production will rise by 35 to 45% (5.7-6.1 million metric tons in 1956), sugar beet by 100%; the total yield of potatoes and vegetables will rise sharply — especially in suburban areas where specialized state farms are established on bottom-land, irrigated and improved bog soils. This huge task can be accomplished only through a considerable increase in agricultural crops, by "introducing a scientific agricultural system adapted to the conditions of the individual economic areas of the country, further specializing and improving the distribution of agricultural products, and by making use of scientific and experimental findings." Premier Khrushchev stressed the great natural importance of introducing an efficient system of agricultural management, especially correct crop rotations. He mentioned the necessity of introducing such rotations during the next seven years on every collective and state farm and of using proper soil cultivation and sowing selected seed.

Work on reclaiming bogs and swampy soils in the northwestern and western regions, extending the area of irrigated soils in the cotton-growing regions, and irrigating arid and moisture-deficit pastures will be continued from 1959-1956.
65.

An unprecedented speeding-up of the development of the chemical industry and, in particular, of plants producing mineral fertilizers, is foreseen during the next seven years. Our agriculture will receive some 31 million metric tons of mineral fertilizers in 1965 as against 10.3 metric tons in 1958. A considerable rise in the stockpiling and use of organic manures is planned, together with widespread liming of acid soils and application of gypsum to solonetzes. The production of insecticides and fungicides for the chemical control of agricultural weeds and pests will be expanded.

A considerable increase in livestock and poultry of all kinds requires a stable feed supply achieved both by an increase in grain production (especially corn) and by substantially raising the productivity of natural pastures and hay meadows, through large-scale reclamation projects, use of fertilizers, etc.

The fulfillment of these plans confronts Soviet Soil Scientists with great tasks. There are two main problems involved: 1) the qualitative calculation and appraisal of the agricultural resources of the USSR; and 2) the development of means for further increasing soil fertility.

The planning of agricultural production, the bringing of new areas under cultivation, the correct distribution and use of fertilizers in the country, the differentiation of cultivation and other agricultural and reclamation methods according to soil groups require more intensive investigations of our country's soils.

A great collective undertaking of our country's soil scientists is to be completed from 1959-1965 — compilation of the State soil map of the area reclaimed for agriculture in the USSR, on a 1:1,000,000 scale — in addition to a classification of the soils of the Soviet Union. Soil and cartographical investigations on the little-studied regions of Siberia and the Far East will be continued and expanded.

Work on soil site index, i. e., the qualitative evaluation of soils with due regard for the economic effectiveness of production expenditures to obtain yields, will be of particular importance in planning agricultural production. In the years ahead, work on the agricultural soil regionalization of the republics, regions, and districts will have to be completed. One of the major tasks for the near future will be the preparation of large-scale soil maps of all our country's collective and state farms. These maps are to be the basic documents for planning crop rotations, differential use of agricultural techniques, application of fertilizers, and for other measures within the area of each farm. Soil Scientists will have to prepare soil maps of many millions of hectares and will work jointly with agronomists in using these maps for efficient exploitation of our agricultural resources.

The second great task of Soil Scientists is to develop methods of increasing soil fertility.

The control of soil fertility is possible only after a profound study of the processes occurring in the soil both under natural conditions and as affected by various agricultural and reclamation measures. The fulfillment of this task demands increased numbers of comprehensive field investigations in the various soil and geographic zones and provinces of our country. One of the urgent tasks in this connection is to work out laboratory and field methods of soil investigation using the latest knowledge in physics and chemistry, particularly isotopic methods.

In the coming years it will be necessary to summarize the data on the agricultural, physical and ameliorative characteristics of USSR soils.

The colossal growth of fertilizer production in the next seven years presents Soviet agricultural chemists with particularly great tasks in developing efficient fertilizer systems, differentiated according to soil groups, and the most convenient techniques and times of applying them, and in studying and introducing new forms of fertilizers, particularly those obtained from industrial wastes. Agricultural chemistry, together with other branches of biology, will play a great part in the development of agriculture.

Particular attention is to be paid during the coming years to devising and bringing into agricultural production measures to control the phenomena causing soil deterioration: water and wind erosion; bog formation and soil salinization. These phenomena are often connected with the unskilled working of the soil and with improper reclamation and agricultural techniques.

The solution of these immense economic problems for the national economy requires not only intense creative work on the part of the whole body of Soviet Soil Scientists, but also a number of administrative measures: a nation-wide organization of research in soils and agricultural chemistry and in soil conservation; and strengthening the soil departments and agricultural chemistry laboratories of the provincial experimental stations and agricultural institutes.

Investigations aimed at solving the previously-mentioned problems will provide a basis for further theoretical developments and for more exact knowledge of the genesis of soil groups, the effect of reclamation on the trend of soil processes, and the cycle of substances in agriculture, etc.

The next 10-15 years should produce a great qualitative improvement in soil science. The steady development of field research into the processes of soil formation and the acquisition of precise quantitative indexes characterizing soil groups and soil formation processes make it possible to describe soil formation phenomena in quantitative terms and to calculate the balance of substances and energy taking part in these processes. Soil Science will thus emerge from the descriptive science that it was in the 19th century into the category of exact sciences.

With every year that passes the international contacts of Soviet Soil Scientists grow and widen. In 1958, delegations of our scientists took part in conferences on soil reclamation and irrigation in the United States of America, on soils of arid regions and methods of soil study in Iran, on soil erosion in Poland, on soil chemistry and fertility in Hamburg, on soil classification in Rumania and Yugoslavia, etc. Soviet Soil Scientists are carrying out important work jointly with those of China, Bulgaria, Albania, Rumania, Burma, Vietnam and other democratic countries. In 1960, Russian Soil Scientists will take part in the 7th International Congress of the Soil Science Society in the United States of America.

The solution of the major problems of importance to the national economy and extension of theoretical investigations require better scientific planning and coordination of the work of USSR Soil Scientists and the strengthening of contacts with scientists of foreign countries.

Inspired by the great and bold plans laid by the party before the Soviet people, the Soil Scientists of the USSR will make every effort to carry out successfully the decisions of the 21st Congress of the Communist Party of the Soviet Union on creating a firm material and technical basis for Communism.

COMPREHENSIVE SOIL RESEARCH AND ITS APPLICATION IN SOLVING SCIENTIFIC AND PRACTICAL AGRICULTURAL PRODUCTION PROBLEMS

VLADIMIR KOSIL, Prague Agricultural Institute

Socialist agriculture places great emphasis on soil as a principal means of production in agriculture. In order to continually improve yields, we should, first of all, study thoroughly the soil properties and processes influencing soil fertility. Knowledge of soil is a principal requirement for scientifically controlling and planning agricultural production, and for dividing it into districts which should be based primarily on the natural and soil-climatic conditions of production. Soil is the chief natural production factor; we should, in a sense, adapt agricultural production to its properties by selecting suitable cultivation methods; yet, we can change these soil properties to meet the demands of agricultural production. Only a thorough knowledge of the soil properties, soil genesis, the dynamics of soil-forming processes, and the factors of productivity will enable us to employ proper measures to improve soils and increase their fertility.

Soil research and soil mapping aimed at solving scientific and practical problems in the agricultural production of Czechoslovakia were begun 50 years ago by Professor Kopetskiy, and later by Professor Novak, Doctor Spirganzliy, and their colleagues. The results of such research proved excellent; however, we should now prepare soil maps to reflect the present-day status of soil science which will answer the need of more direct participation in solving agricultural problems. During the past three years, a system of soil research based on scientific production has been worked out — which we shall hereby refer to as comprehensive soil research.

Comprehensive soil research aids in solving not only the important practical problems of increasing soil fertility, but also questions of soil genesis, classification, typology, etc. A study of the dynamic soil properties should be systematically carried out under conditions characteristic of the various soil taxonomic units. After a prolonged study of the changes in soil properties, we should be able to set up general patterns for the specific conditions. This constitutes the basis for the active influence of the human factor on soil-formation processes with the aim of continually improving soil fertility.

In order to conduct our research and experimentation in various branches of agricultural sciences we must make use of the area where comprehensive soil research has been carried out.

A comprehensive soil study consists of three related stages: 1) field soil and agricultural-chemical research; 2) control of proposed measures in the area under study (a system of vegetative experiments); and 3) application of the results obtained for working out scientific problems.

Each of the subsequent stages organically develops the scientific and practical content of the preceding stage and forms the basis for solving the actual problems in agricultural production and science.

The chief purpose of comprehensive research is to produce a maximum effect in scientific research for assuring high yields.

Comprehensive study begins with field research. At this stage, a detailed soil study is made in a specific area, as a rule in an area of 200-400 sq km. The field study provides a soil map, cartograms, and a report on soil research. The area under study is described in terms of agricultural productivity (economic feature), climatic, geomorphologic, geologic, and phytocenologic conditions, and by the influence of the human factor.

A soil map contains a colored territorial distribution of genetic soil groups and genetically productive areas.

The genetic soil groups, as basic taxonomic units, are determined in the field by morphologic and stratigraphic features of soil profiles, are precisely defined, and are supplemented by an analysis of soil samples. In the laboratory, the texture, physical properties, carbonate content and pH value of KC1 and H_2O extracts are studied; saturation of the adsorbtion complex, the humus content (according to Tyurin) and of total nitrogen content, available P_2O_5 (determined by Egner) and K_2O (determined by Shakhtshabel') are determined and an extract of a 20% solution of hot HC1 analyzed. As we see, the methods which make possible mass analyses of soil samples are used for determining the laboratory characteristics of soil groups. More detailed analyses are undertaken to solve scientific problems, such as the determination of humus components, identification of clay minerals, etc.

To establish a genetic classification for soils by comprehensive soil research, we used a system consiting of the following taxonomic units:

1) Stage of the soil-forming process — the podzolic, sod-podzolic, podzolic-sod, chernozem, meadow, bog and solonetz;

2) Soil groups — the podzolic, sod-podzolic, brown forest soil, gray forest soil, rendzina, chernozem, sod, meadow, bog soils, solonchak, solonetz, and solodi;

3) Subgroups and species — determine the secondary super-imposition of another stage of a soil-forming process upon the primary stage, and the degree of its development;

4) Sub-species — indicates the degree of erosion, accumulation, and development of soil;

5) Type — describes the texture;

6) Variant — varies according to parent material;

7) Degree of cultivation — (after Ivanova).

The peat soils are a special group that are separated by genesis and by the principal groups of plants growing on them. The system includes 1) the undeveloped soils whose texture has been described in greater detail, and 2) parent material.

The proposed classification system is checked during comprehensive soil research by morphologic and stratigraphic features, as well as by the results of laboratory research, in order to arrive at an objective basis for setting up a genetic classification of soils in Czechoslovakia.

Dividing Districts by the Genetic Productive Feature

The districts marked on a soil map are, in part, areas containing a specific combination of soil-forming factors, and, consequently, a peculiar (original) horizon. The following criteria are used to delimit the soil districts: the homogeneous (in a certain sense) properties of the horizon, the bio-climatic conditions (climatic, phenologic, and phytocenologic), underlying rock, the geomorphologic and hydrologic conditions, and soil cultivation.

The natural conditions, history of the landscape, and the rate of agricultural production are combined in a specific complex with the conditions of agricultural production, so that the districts incorporate the natural and economic conditions and, thus, are a useful taxonomic unit for describing the territorial complexes.

A soil map — basically, a map of genetic soil groups — is supplemented by using the results of field and laboratory research with cartograms showing the individual soil properties, such as underlying rock, soil texture, acidity of plowed layers, the need for liming, and the amount of P_2O_5 and K_2O available to plants. These cartograms complete the genetic characteristics of soils.

A report on soil research accompanies the soil map and cartograms and is divided as follows showing:

A) The characteristics of agricultural productivity and natural conditions in the area under study: 1) the agricultural-productive conditions (soil structure, seed germination, structure of sown areas, yields, use of organic and mineral fertilizers, soil cultivation system, etc.); 2) climatic conditions (mean annual temperature, mean temperature in July and January, mean precipitation, phenologic data); 3) geomorphologic and geologic conditions; and 4) phytocenologic conditions and the human activity.

B) Characteristics of the districts and a description of the soil groups.

C) Measures for increasing soil productivity: 1) utilization of the available soil; 2) soil cultivation; 3) soil improvement; 4) fertilization; and 5) improvement of meadows and pastures.

D) The last part summarizes the results from which we have derived the soil characteristics and indicates measures for increasing soil fertility. This part of the report contains a systematic list of soil groups (and additional taxonomic units), gives characteristics of the soil-forming process, of the separate groups and subgroups from the morphology and stratigraphy of the profiles and from analytical data (presented in tables along with a schematic of the characteristic soil profiles).

In 1957, comprehensive soil research was carried out by this method in the Zhamberk district over a 326 sq km area of farm land. A total of 3, 645 profiles (to a depth of 120-150 cm) and several thousand holes were dug. A particle-size analysis was made for 11, 744 selected soil samples; available P_2O_5 and K_2O were determined for 2, 523 samples; for 1, 639 samples, chemical (extract of a 20% solution of hot HC1) and physicochemical analyses were made; and physical properties were analyzed for 1, 072 samples. Twenty-two soil scientists participated in this work. The cost of work computed per 1 hectare was 4. 80 koruny.

This proposed system of comprehensive soil research, applied to one district, was the first step in the development of soil research in Czechoslovakia. This system can be used both for scientific research and for solving socialist agricultural production problems.

Based on the results obtained, a plan was drawn up for conducting comprehensive soil research in Czechoslovakia employing all three stages by 1975. The purpose of this research is to procure reliable data for experimental work, to divide agricultural production into districts, to provide for all-round improvement of production, and for site quality, etc.

From the scientific viewpoint, comprehensive soil research enables us to study thoroughly the soil-forming process, work out the basic genetic characteristics of soil groups, study the special problems involved in the dynamics of soil properties, and develop methods for studying them.

Czechoslovakian soil scientists realize that comprehensive soil research is the principal means for further developing soil science and for actively contributing to socialist agricultural production.

Received June 11, 1958

THE COMPOSITION OF ORGANIC SUBSTANCES AND THEIR RELATIONSHIP TO THE MINERAL PORTION OF THE SOIL

D. V. KHAN, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Organic substances in soils are usually studied without considering their relationships to the mineral portion of the soil. However, the formation of mineral-organic complexes appears to be one of the most important processes in soil formation and the basis for its fertility. Therefore, the study of the various relationships of organic matter to the minerals and cations in soils have practical and theoretical significance. Several studies (2, 3, 12, 16, 21) have been made in this field.

We attempted to determine the amount and some of the chemical properties of organic matter associated with different soil minerals using samples of mineral-organic complexes separated directly from various soils:

1) Meadow chernozem from Voronezh Oblast', V. V. Dokuchayev Agricultural Institute;

2) Dark-colored, sod-meadow, gley soil from Amur Oblast';

3) Chernozem on loess-like clay loam from Kursk Oblast'; and

4) Moderately podzolized sod soil from Moscow Oblast'.

Basically, fractions containing the mineral-organic complexes were separated from the soil samples by centrifuging and decanting. A separate of less than one micron in diameter was obtained by decanting[1] from the original sample. Remaining separates $>1\ \mu$ in diameter were obtained by centrifuging with a Moshev gyrostat using Toulet solutions having specific gravities of 2. 45, 2. 30, and 1. 80. In order to obtain the most homogenous separates possible, each was centrifuged and decanted four times. The composition of the separates was checked with a polarizing microscope.

The method of separating soil samples by centrifuging and decanting, using Toulet solutions of different specific gravities, is diagrammed in Figure 1.

Thus, separates were obtained by using solutions with specific gravities of >2.45, 2. 45-2. 30, 2. 30-1. 80, and <1.80. The latter two contained the highest concentrations of organic matter. Five separates were obtained from each soil sample by the foregoing methods. Data for the quantitative distribution of organic matter in these separates are given in Table 1.

Fractions differ greatly in organic matter content. The largest amount (34%-44%) quantity occurs in the separate having a specific gravity of <1.80. Next, the separates having specific gravities of 1. 80-2. 30 and that of $<1\ \mu$ in diameter contain 7%-18% and 5%-9% organic carbon, respectively. The two heavy fractions contain an insignificant amount of organic carbon (1%-14%), and were not tested.

If the organic matter in each separate is expressed as a percentage of that in the original soil, the following data are obtained. The chernozems and the Amur Oblast' soil contain 75%-78% in the separates <0.001 mm in diameter and in the podzol, 58%. Percentages were 5%-23% and 10%-14%, respectively, in the separates obtained from Toulet solutions having specific gravities of 1. 80-2. 30 and <1.80.

From the foregoing we may conclude that a preponderance of organic matter is concentrated in three soil separates obtained by centrifuging and decanting, using Toulet's solutions having specific gravities of 2. 30-1. 80 and <1.80.

We now consider the composition of these three separates. The <0.001 mm separate,

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[1] A decantation method suitable for soils was proposed by Aydinyan (4) and developed further in Gorbunov's research (5).

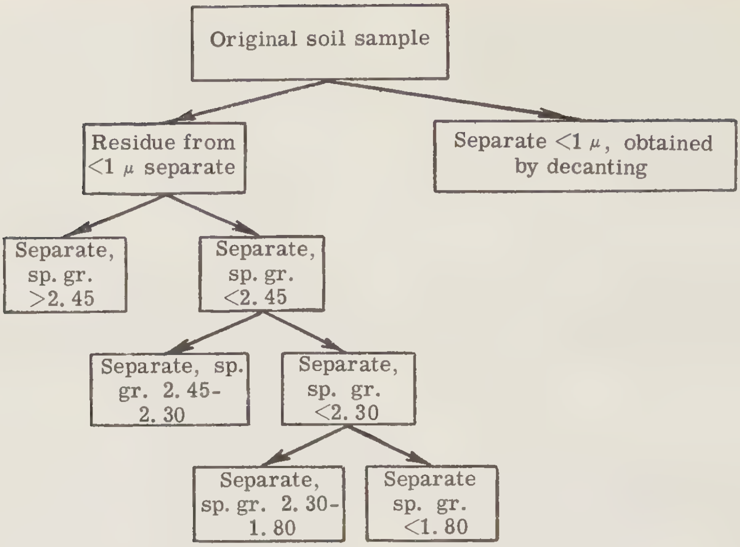
Original soil sample
Residue from <1 μ separate
Separate <1 μ, obtained by decanting
Separate, sp. gr. >2.45
Separate, sp. gr. <2.45
Separate, sp. gr. 2.45-2.30
Separate, sp. gr. <2.30
Separate, sp. gr. 2.30-1.80
Separate sp. gr. <1.80

Fig. 1. - Diagram of dividing soil samples into separates by decanting and centrifuging.

Table 1

Distribution of soil separates and their organic content

Soil	Specific gravity	Weight of the separate in 100 of soil	Carbon content in % of separates	Carbon in % of total separate	Carbon content of separates in % of original soil carbon
Chernozem, Voronezh Oblast'	< 1.80	1.60	43.60	0.69	14.78
	1.80—2.30	3.40	7.50	0.25	5.35
	2.30—2.45	3.00	1.04	0.03	0.64
	>2.45	49.00	0.13	0.06	1.28
Its <0.001 mm separate		43.00	8.50	3.64	77.94
				4.37	
Dark colored, sod-meadow soil, Amur Oblast'	<1.80	1.45	44.45	0.64	12.14
	1.80—2.30	2.90	18.54	0.53	10.00
	2.30—2.45	3.55	1.60	0.05	0.95
	>2.45	48.00	0.23	0.08	1.54
Its <0.001 mm separate		44.00	9.00	3.97	75.33
				5.27	
Chernozem, Kursk Oblast'	<1.80	1.20	44.63	0.53	12.64
	1.80—2.30	3.02	7.20	0.34	8.11
	2.30—2.45	3.13	1.00	0.03	0.71
	>2.45	55.05	0.12	0.06	1.40
Its <0.001 mm separate		37.70	8.60	3.23	77.10
				4.19	
Podzol soil, Moscow Oblast'	<1.80	0.50	34.40	0.17	10.43
	1.80—2.30	3.11	12.27	0.38	23.31
	2.30—2.45	6.10	1.20	0.07	4.30
	>2.45	73.18	0.07	0.05	3.00
Its <0.001 mm separate		17.10	5.64	0.96	58.89
				1.63	

according to X-ray and microscopic tests, is a mixture of minerals, chiefly of the montmorillonitic group. They therefore possess a high adsorption capacity for organic matter. This is confirmed by the data in Table 1 giving the organic carbon content in the separates obtained from various soil groups by decanting. In all separates it amounted to 6%-9%.

Separates obtained with Toulet solutions having a specific gravity >1.80 from the chernozems and the Amur Oblast' soil, were uniform, dark masses resembling carbon (Figure 2). The same fraction separated with Toulet solutions from the podzol soil were dark brown in color.

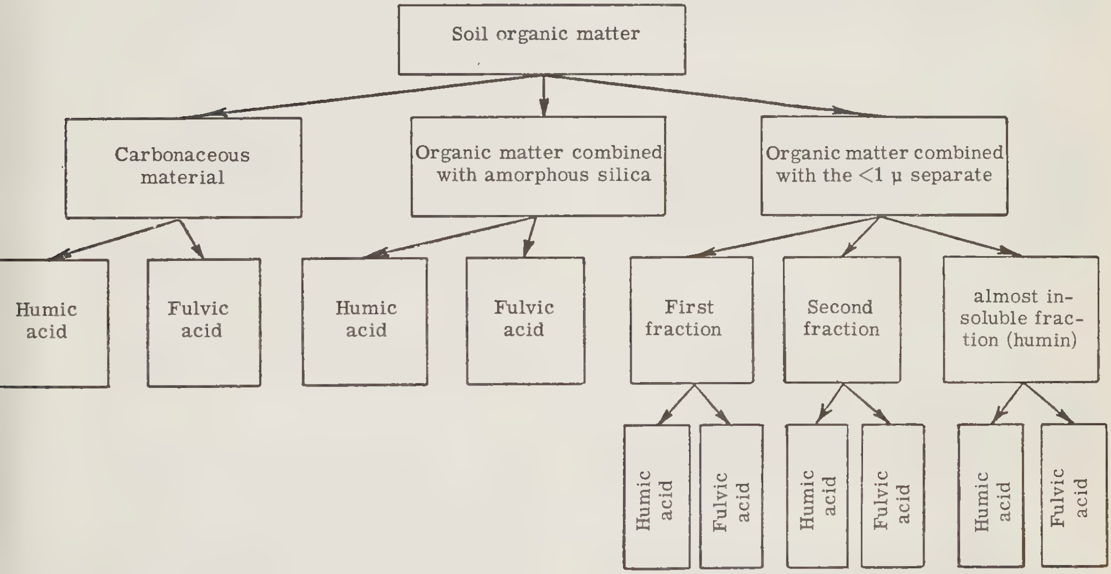

Fig. 2. - Composition of organic matter and its bonding with the mineral portion of the soil.

The carbon, nitrogen, and ash content in this separate from various soil types are given in Table 2.

Data in the table show a considerably higher carbon content in the chernozems and the Amur Oblast' soil separates than from the podzol. All separates are characterized by a high carbon content of 50%-55% calculated on an ash-free, dry basis. We conclude that in these separates, organic matter is not combined with the mineral portion of the soil, but exists in a free state. The rather high ash content is due mainly to mechanical admixture, and may be reduced to a minimum by further purification.

We next note that these separates are partially soluble in a 0.1 N alkali solution. After separating the soluble organic matter, the carbon content of the residue was determined. It was very high, amounting to as much as 68%. The high carbon and low nitrogen content of the separates tested appears to be characteristic of carbonaceous substances. Kukharenko (10) obtained similar data.

Separates obtained from Toulet solutions having a specific gravity of from 1.80-2.30 were dark gray masses and under the microscope appeared to consist only of biogenic forms of amorphous silica as described by Tyurin (13). In this fraction from the Amur Oblast' soil, the carbon content was 18% and in the other soils, 7%-12%. The organic matter in these separates was also partially soluble in a 0.1 N alkali solution.

Separates obtained from Toulet solutions having a specific gravity between 2.30-2.45 contained a mixture of minerals, predominately hydrous mica. The percentages of organic matter in the chernozems and Amur Oblast' soils were 1%-1.6% and in the podzols, 3%-4%. In the last separate, large amounts of quartz and other minerals were present and they contained insignificant amounts of organic matter (1%-3%).

Thus 60%-78% of the organic matter in the

Table 2

Carbon, nitrogen, and ash content in the soil separates of a sp. gr. of <1.80

Soil	Carbon, %	Moisture, %	Ash, %	Absolutely dry and ash-free, %	
				Carbon	Nitrogen
Chernozem, Voronezh Oblast'	43.60	10.42	10.50	55.00	1.70
Soil, Amur Oblast'	44.63	7.00	9.00	53.00	2.10
Chernozem, Kursk Oblast'	44.45	5.10	12.90	54.20	2.00
Podzol soil, Moscow Oblast'	35.00	13.05	16.20	50.00	Not det'd.

soil was associated with separates of less than one micron in diameter, (clay minerals of the montmorillonitic group), 5%-23% with amorphous silica (phytolites), and 10%-14% occurred in the free state.

Further investigations were devoted to the characteristics of the composition of the organic matter contained in the previous soil separates. We attempted to separate the organic matter in the soil samples tested. It should be pointed out that several authors (1, 6, 8, 11, 14, 15, 20, 22) have already investigated this objective.

The immediate objects of study were the organic materials extracted without decalcification of an 0.1 N alkali from the separates of carbonaceous material, amorphous silica, as well as the clay separates (clay minerals of the montmorillonite group). Humic and fulvic acid contents were determined in the extracted organic material. These data are given in Table 3.

In all cases the ratio of humic to fulvic acids was highest in the carbonaceous material. Organic matter contained in the amorphous silica fraction was next (Phytolites). The lowest ratio was found in the <1 μ separate (clay minerals of the montmorillonite group), in which the ratio of humic to fulvic acids was less than one. The podzolic soil was especially noteworthy in this respect. Organic matter extracted from it consisted chiefly of fulvic acid.

Of these data, greatest interest is in the organic matter extracted from fractions of less than one micron in diamater. A lower ratio of humic to fulvic acids was observed in them than in organic matter extracted with alkali after decalcification. This circumstance led us to compare the tests of the organic matter extracted from the <1 μ fraction with alkali before and after decalcification. Here we must point out that These organic materials were studied by Shmuk (17), Tyurin (15), and Kononova and collaborators (9). However, chemical and other properties of these materials are still inadequately known.

In our work we attempted to fill this gap to some degree. The following method was used to prepare the organic matter. Suitable amounts of the <1 μ diameter separate were covered with a 0.1 N alkali solution, Na_2SO_4 was added as a flocculating agent, and stirred several times with a glass rod. The alkaline solution was filtered through a large Nutsch funnel over a 24-hour period. This operation was repeated until the soluble organic matter was completely extracted. The alkaline solution collected was passed through a Chamberlain filter candle to rid it of solid contaminants. The humic acids were precipitated with sulfuric acid. The sulfate precipitate was dialyzed through a collodion membrane and dried on a water bath at a temperature of approximately 40° C.

After completion of the alkali treatment, the soil was washed with water until free of NaOH and decalcified with 0.05 N sulfuric acid. We should note that calcium and aluminum were detected in the acid extract. There was no iron present. After treatment with sulfuric acid, the soil was rewashed with water until free of sulfate, and covered with a 0.1 N alkali solution in order to extract an additional separate of organic matter. Subsequent operations were the same as before. Thus, two separations of organic matter were obtained from the <1 μ diameter separate. For convenience in the following discussion we shall designate the organic matter extracted before decalcification as the first fraction, and that extracted after decalcification as the second.

First of all, the quantities of the first and second fractions of organic matter were determined in the <1 μ diameter separates obtained from different soil groups (Table 4).

Again we demonstrated that the <1 μ diameter separate has a considerable capacity to fix soil organic matter. Because of this fact the amount of organic matter is two to four times greater in this separate than in the original soil.

Table 3

Ratios of humic to fulvic acids in soil separates obtained by Toulet solutions of different sp. gr. and by decanting

Soil	Preparations from separates	Specific gravity or diameter of separate	Humic acid		Fulvic acid		Ratio Humic acid / Fulvic acid
			g	%	g	%	
Voronezh Oblast'	carbonaceous material	<1. 80	0. 54	78	0. 15	22	3. 60
	amorphous silica	1. 80—2. 30	0. 16	64	0. 09	36	1. 80
	soil <1 μ	<1 μ	1. 46	48	1. 54	52	0. 90
Amur Oblast'	carbonaceous material	<1. 80	0. 54	70	0. 10	30	5. 40
	amorphous silica	1. 80—2. 30	0. 20	71	0. 08	29	2. 50
	soil <1 μ	<1 μ	1. 32	40	1. 98	60	0. 67
Kursk Oblast'	carbonaceous material	<1. 80	0. 39	73	0. 14	27	3. 00
	amorphous silica	1. 80—2. 30	0. 22	69	1. 12	31	1. 80
	soil <1 μ	<1 μ	1. 22	42	1. 64	58	0. 75
Podzolic soil from Moscow Oblast'	carbonaceous material	<1. 80				Not determined	
	amorphous silica	1. 80—2. 30				" "	
	soil <1 μ	<1 μ	0. 47	18	2. 13	82	0. 20

Table 4

Contents of various groups of organic matter in the <1 μ diameter soil separate

Soil	Organic carbon content, %	Carbon content 1st fraction		Carbon content 1st fraction		Residue from the separate	
		g	%	g	%	g	%
Chernozem, Voronezh Oblast'	8. 50	3. 00	35. 00	3. 20	37. 00	2. 30	23. 00
Chernozem, Kursk Oblast'	8. 60	2. 86	33. 00	3. 06	35. 00	2. 68	32. 00
Dark-colored meadow-sod soil, Amur Oblast'	9. 00	3. 30	36. 00	3. 50	39. 00	2. 20	25. 00
Podzolic soil, Moscow Oblast'	5. 64	2. 60	46. 00	1. 20	22. 00	1. 80	32. 00

Of the total organic matter in the separate, about 70% is relatively easily soluble. The nearly insoluble residue is conditionally assumed to be humins. No substantial differences are observed between the humus content of the individual separates in the chernozems and the Amur Oblast' soil. The podzolic soil however, is somewhat different, in that the first organic matter fraction is considerably larger than the second.

In addition to the quantitative evaluation of ndividual fractions of organic matter, they were later subjected to qualitative analysis. Ratios of humic to fulvic acids were determined (Table 5).

The data show that fulvic acids predominate over humic acids in the first organic fraction extracted with alkali before decalcification. The podzolic soil demonstrates this especially well, since its first fraction is mainly fulvic acid.

The second fraction, extracted with alkali after decalcification is very different. It contains four to eight times more humic acid than fulvic acid. Fractions from the chernozems

Table 5

Ratios of humic to fulvic acids in various organic matter fractions obtained from the <1 μ diameter soil separates

Soil	First organic matter fraction				Ratio Humic acid/Fulvic acid	Second organic matter fraction				Ratio Humic acid/Fulvic acid
	g	%	g	%		g	%	g	%	
	Humic acid		Fulvic acid			Humic acid		Fulvic acid		
Chernozem, Voronezh Oblast'	1.42	47	1.58	53	0.90	2.85	89	0.35	11	8.10
Chernozem, Kursk Oblast'	1.22	42	1.64	58	0.74	2.60	86	0.46	14	5.70
Dark-colored, meadow-sod soil, Amur Oblast'	1.32	40	1.98	60	0.67	2.94	84	0.56	16	5.20
Podzolic soil, Moscow Oblast'	0.45	20	2.15	80	0.25	0.80	44	1.00	56	0.80

and Amur Oblast' soils are especially rich in humic acid. In the podzolic soil as well, there was a considerable amount of humic acid as compared to that of the first. Thus, we conclude that the two organic fractions differ markedly from each other. Data for their chemical composition also verify this (Table 6).

Table 6

Carbon and nitrogen content in the humic acid fraction obtained from <1 μ soil separate

Humic acid preparation	Fraction No.	Element. cont.	
		C	N
Chernozem, Voronezh Oblast'	first	57.05	6.05
	second	61.45	3.44
Chernozem, Kursk Oblast'	first	56.45	not det'd.
	second	59.81	not det'd.
Podzolic soil, Moscow Oblast'	first	53.29	7.70
	second	58.20	6.27

These data show a distinct difference in chemical composition between the first and second fractions. In all cases, the carbon content was lower in the first humic acid fraction than in the second. The difference between the two was especially distinct in the humic acid obtained from the <1 μ separate from the podzolic soil. The relationship with respect to nitrogen content was reversed, being considerably greater in the first humic acid fraction from the chernozem and podzolic soil than in the second.

Thus, the <1 μ diameter separates contain various types of humic acids. We recall that in addition to the indicated groups of organic matter, a portion occurs as nearly insoluble compounds (humins), which are also extracted with alkali after strong treatment with mineral acids. According to the data of Tyurin (12), Khan (18), and Zyrin (7), humin is similar in chemical composition to the humic acid group. Thus, organic matter in the <1 μ diameter separate can be divided into three groups each of humic and fulvic acids. If another two groups of humic and fulvic acids, separated from the carbonaceous material and amorphous silica are added to them, we obtain five groups of humic and fulvic acids. Accordingly, the composition of organic matter in soils may be represented schematically as follows.

Figure 2 indicates that the sources of the extracted groups of humic and fulvic acids in the soil are rather varied. Depending on the source, the extracted acids probably have different chemical properties. Some data with respect to humic acid are presented in Tables 5 and 6. All data indicate a very complex composition of organic matter in soils. Detailed tests of the chemical composition and other properties of the humic and fulvic acid groups will make possible a better understanding of the processes of soil formation.

In characterizing the composition of organic matter, one must consider the nature of their bonds to the mineral portion of the soil. Here, we consider the organic matter obtained from the amorphous silica and <1 μ diameter separates. The presence of organic matter in the amorphous silica separate can be explained by its biological origin. It is recognized that many plant families are siliceous. Humification of these siliceous plants results in the accumulation of both organic matter and amorphous silica. Thus, the accumulation of organic matter in the amorphous silica separate may be regarded as a mechanical mixture.

We look upon the bonding of humic and fulvic acids with a <1 μ diameter separate of the soil as follows.

The first group of organic matter, extracted with 0.1 N alkali before decalcification, is bonded chiefly with calcium, aluminum, and iron, adsorbed on the montmorillonitic clay mineral surfaces. This is confirmed by laboratory tests on the solubility of humic acids adsorbed on askanite previously saturated with the previously-mentioned cations. Most of these humic acids became soluble when treated with 0.1 N alkali (18).

A significant amount of the organic matter extracted with 0.1 N alkali after decalcification is apparently bonded to the soil in another way. The following observations may be cited as corroboration. It is usually assumed that treating the soil with mineral acids destroys the bonds of mineral-organic complexes. At the same time a corresponding number of cations which fixed the organic matter, goes into the acid extract. We determined the composition of the cations going into the decalcinate. Small amounts of calcium and aluminum were observed, but no iron was present. This lack cast doubt upon physical-chemical bonding of the second group of organic matter, especially since about 30%-40% of the organic matter, bonded with cations, had already been extracted in the first group. There is some reason to assume that a considerable portion of this group of organic matter is chemically bonded. Mineral acids lead to destruction of these chemical bonds, and split off separate structural units from the complete molecules of organic matter as humic and fulvic acids and other components readily soluble in 0.1 N alkali.

CONCLUSIONS

1. A scheme was presented for dividing soils into separates having different organic matter content. It was demonstrated that about 92%-97% of the organic matter in soil was concentrated in three soil separates. Of this, 60%-70% was associated with the <1 μ diameter separate (clay minerals of the montmorillonite group); 5%-23% was observed in the amorphous silica separation (phytolites); 10%-14% was found in the free state.

2. It was established that the organic matter in these three separates was partially soluble in alkali as humic and fulvic acids. Thus, by using the previously described scheme, the organic matter was successfully fractioned into a series of groups of humic and fulvic acids.

3. Of all the soil minerals present in the soil, the most significant for fixing organic matter are the clay minerals of the montmorillonitic group. From these soil minerals, two fractions each of humic and fulvic acids were separated.

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STUDY OF THE INTERRELATIONSHIPS OF VEGETATION AND SOIL IN THE KARELIAN ISTHMUS

T. A. ROZHNOVA and L. S. SCHASTNAIA, V. V. Dokuchayev Central Museum of Soil Science, Academy of Sciences, USSR

The well-known ideas of V. I. Vernadskii and B. B. Polynov on the role of living matter in the earth's crust served as a basis for developing the present-day biogeochemical trend in Soviet soil science. The method used to study rocks, soils, vegetation and natural waters on the combined elements of the surface — the watersheds and depressions — represents the foremost method of this trend for explaining the transformations and relationships of the migrating elements under different natural landscapes.

The combined study of soils and vegetation is beginning to attract an ever increasing circle of scientists, primarily in the geographic-genetic field of soil science. As we know, a number of new studies and reviews (1, 2, 3, 8, 11, 14, 15, 16, 17, 21) have appeared within the past ten years, which have broadened our concept of the role of the mineral composition of vegetation in soil formation and the biological cycle of matter. But most of these data deal with soil vegetation zones in the south or with mountain districts and only very slight work on the taiga forest zone. Concerning the latter, we should mention the recently published new studies on the northwestern districts by Ponomareva, Miasnikova (13) and Evdokimova (4) -- and, based on earlier research -- separate studies by Tatarinov (20), Zaitsev (7), Stepanov (19), Remezov, Smirnova (17, 18), etc.

Our study is the first attempt to examine the interaction of vegetation and soils under conditions typical of the northern districts of the Karelian Isthmus, in order to describe soil formation characteristics of different vegetative types under successively changing conditions of topography and soil moisture regime. At the same time we shall pay particular attention to the biological accumulation of ash elements and the nature of their movement in the litter.[1]

The district with which we are concerned is located west of Vyborg in the region of the Scandinavian shield composed of Rapakivi granite. The glacier-formed rocks run north-northwest in the form of sloping ridges, forming a typical hollow ridge (steep-sided promontory) landscape. The promontory peaks are mostly eroded and exposed; the slopes are covered with a thin illuvial deposit of boulder sand while in the depressions we find assorted (graded) lacustrine-glacial sandy loam and clay loam deposits, often of banded structure. The area of our study falls in the central taiga zone characterized basically by sporadic swamped forests of spruce, moss and whortleberry. Along the edges of the lake-like hollows, which are covered with soil suitable for agriculture, are found insular areas of mixed grass forests.

We can see from our profile the distribution pattern of vegetation and soils under these conditions. The 300 meter profile runs from the peak of the promontory ridge northeast along the slope of the ridge to the lacustrine-glacial hollow (ravine). Six profile numbers are shown, four of them will be discussed in detail here (Figure 1).

Profile No. 1. Located on the watershed peak of the granite promontory covered by large spots of bushy lichens (Cladonia alpestris), indicating the primitive accumulative soil. A thin layer of dark humified fine earth including crystalline rock fragments is developed under the lichen cover.

The role of Cladonia alpestris in the initial soil formation stage has been examined very

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[1] Of similar nature are our comparative studies in other natural regions of the Karelian Isthmus. These data are presently being processed. Data gathered on the northern district for this purpose by the 1956 expedition of the Central Museum of Soil Science were used by L. S. Schastnaia as the basis for her thesis written at Leningrad State University under Professor A. A. Zavalishin's direction. The remaining data were processed at the Soil Science Museum.

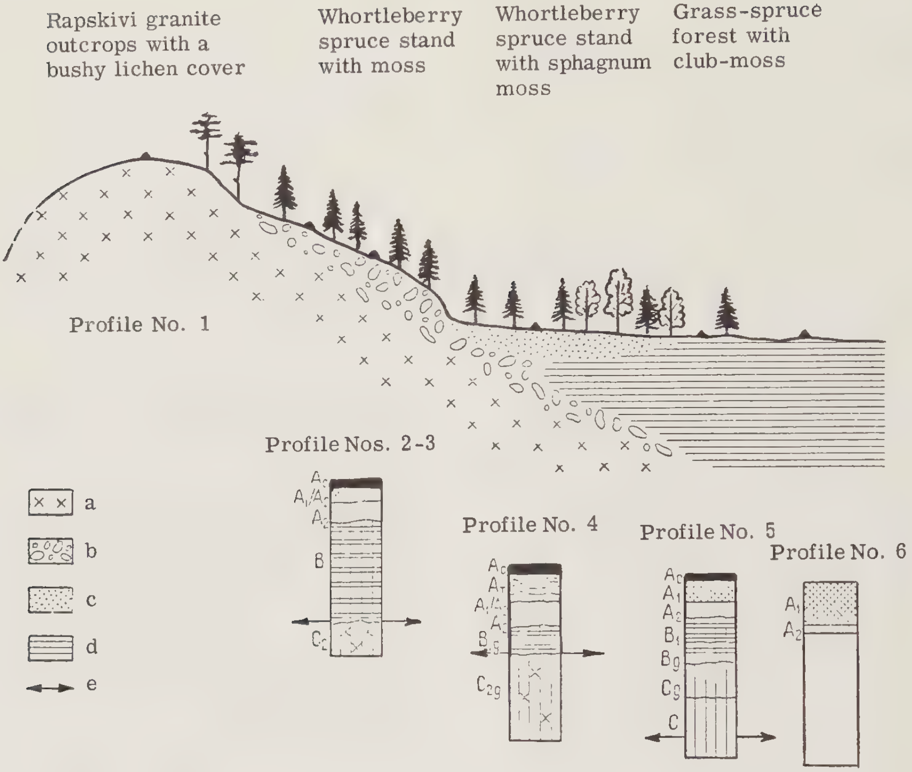
Rapskivi granite outcrops with a bushy lichen cover
Whortleberry spruce stand with moss
Whortleberry spruce stand with sphagnum moss
Grass-spruce forest with club-moss
Profile No. 1
Profile Nos. 2-3
Profile No. 4
Profile No. 5
Profile No. 6
a
b
c
d
e
A0
A1/A2
A2
B
Cc
A0
AT
A1/A2
A2
Bg
C2g
A0
A1
A2
B1
Bg
Cg
C
A1
A2

Fig. 1. - Schematic profile in the Vyborgskii rayon as seen from the top of the promontory to the lacustrine-glacial lowlands.

Profile No. 1 - a primitive accumulative soil. Profile Nos. 2-3 - peaty-strongly-podzolic ferruginous humus soil; horizons and depth: A_0 0-6 cm, A_1/A_2 6-14, A_2 14-28, B 28-75 cm. Profile No. 4 - peaty strongly-podzolic gleyed soil; horizons and depth: A_0 0-7 cm, A_T 7-16, A_1/A_2 16-20, A_2 20-36, B_{1g} 36-53 cm. Profile No. 5 - Sod medium-podzolic gleyish soil; horizons and depth: A_0 0-3 cm, A_1 3-15, A_2 15-25, B_1 25-38, B_g 38-52, C_g 52-70 cm. Profile No. 6 - cultivated sod-podzolic gleyed soil; horizons and depth; A_1 0-22, A_2 22-26 cm.

a - crystalline rock; b - coarse boulder sandy loam; c - sand with a mixture of gravel and cobbles; d - stratified fine clay loam; e - ground waters.

little; however, we shall study these lichens under Karelian Isthmus conditions not only as epiphytes (5), settled on the substratum and developed by crustaceous lichens but also as lithophytes, since they cover the surface of the totally eroded granite extensively and have a direct effect upon it. Our observations agree with Levin's (8) studies, which show that the hypha of these lichens are capable of penetrating the rock and composing it biochemically.

We should point out that the water regime of the primitive soils on the promontory is completely dependent upon rainfall and that there is a constant moisture deficiency. This considerably prevents the mineral matter from dissolving and being leached from the soil. But, during periods of heavy rain or melting of snow, the rapid flow of waters from the top of the promontory is conducive to the disintegration and removal of fine earth. The waters filtering down the slope carry off the decomposition products of the crystalline rocks and the organic residue which gradually enrich the foot slopes.

Profile No. 2. Located on the upper fairly steep part of the slope of the promontory with a coarse sandy loam moraine cover. At a depth of 73 cm the sandy loam soil is covered with a litter of granite slab. The water percolates as it comes in contact with the slab. A spruce forest with a surface cover of moss Pleurozium schreberi and whortleberry is developed on the surface. The soil is peaty, strongly podzolic, ferruginous-humified, with clearly expressed podzolic and illuvial horizons (A_0 0-7 cm, A_1A_2 8-14, A_2 14-30, B_1 30-60, C_1 60-73 cm).

Profile No. 4. Located beneath the spruce and sphagnum at the foot of the promontory on a sloping diluvial deposit strip in the direction of the lacustrine hollow. From the slope we observe a ground water flow which causes the surface to waterlog and the sphagnum to develop. The soil is peaty, strongly podzolic, gleyed on a two-layered drift; from 36 cm down, the moraine coarse sandy loam is covered with a layer of fine clay loam; the water slowly oozes out at the edge of the two layers and becomes stagnant (A_0 0-6, A_1 6-15, A_1A_2 15-20, A_2 20-36, B 36-63, C 63-90 cm).

Profile No. 5. Occupies the lowest topographic element on the profile located at the periphery of the lacustrine-like hollow. On the surface is developed a birch-pine forest with an undergrowth of deciduous species and a growth in the surface cover of Deschampsia flexuosa, Oxalis acetosella, viola, Majanthemum bifolium, and Asarum aeuropaeum. The soil is sod-moderately podzolic, gleyey, on a fine clay loam, becoming a banded structure in the lower part. The water appears at a depth of 1 m (A_0 0-3, A_1 3-15, A_2B_1 15-27, B_1 27-38, B_{2g} 38-52, C_{1g} 51-90, C_{2g} 90-115 cm).

To describe each profile number, green vegetation, litter samples, soil horizons, soil forming parent material and ground water samples were collected in September 1956; water samples were taken again in the spring of 1957. Special attention was paid to the soil litter where the layers were separated as much as possible by the different degrees of decomposition of the plant residue. The general chemical characteristics of these soils are found in Table 1.[2]

We shall begin our examination of the results of our experimental studies with the primitive-accumulative soil (Table 2). Data show that the lichen Cladonia alpestris has a very low ash content (1. 9%) of which silica is the predominant element. Potassium is found in considerable quantities with smaller amounts of the other elements.

The lichens utilize the minerals of atmospheric silt; the importance of this silt, however, has never actually been taken into account. Yet, in accordance with mineralogical data on silt composition, several scientists (9, 21) have assigned to silt a secondary role in the accumulation by lichens of a series of elements -- the organogenes (S, P, Ca). A considerably high percentage of these elements in the lichen makes it possible to correlate them more easily with the mineral substratum. All the ash elements in the lichens, arranged by absolute amounts, form the series shown in Figure A.

By comparing the distribution order of the elements for the lichen with similar data borrowed from literary sources, we see that there are quite large differences in the amounts of S, P, K and Ca in the separate species of bushy and leafy lichens on various rocks. The specific character of the ash composition of lichens is explained primarily by their generic peculiarities, but may depend considerably on the mineral composition of the rocks. Such dependence is clearly evident, for example, on limestone where calcium (Levin series) is first accumulated in the lichens. Similarly, we can examine the potassium concentration in our lichen on granite enriched by potash feldspar.

We also know that the ability of the plant organisms to select makes it possible for them to absorb intensely and concentrate the most important nutrients which are often in a dispersed state in the rock. Thus, the composition of the bushy lichens developed on the sand deposits of the Karelian Isthmus (Ponomareva's series) is of interest to us. Despite the barren character of the mineral substratum, these lichens differ by their extremely high concentration of P and S; from Ponomareva's data (13) they assume the role of being active agents in podzol formation. The absence of a similar specific character in the composition of lichens on crystalline rocks may essentially affect the nature of their action on the soil process.

Below are given the absorption series for the bushy lichen Cladonia and, for comparison purposes, the leaf-like lichen Parmelia on granite-gneiss (16); the series for Cladonia on Rapakivi granite is P-S-Ca-Mg-K-Fe-Si-Al; the series for Parmelia on granite gneiss is P-(S)-Mg-Ca-K-Fe-Si-Al.

Both series indicate the largest relative (comparative) accumulation of elements — the organogenes — P, S and, to a lesser degree, Ca, Mg, K; Fe, Si and Al are last. Consequently, the bushy lichens, together with the typical lithophylic organisms, may be collectors of the ash elements most important for plant nutrition.

The fine earth under the lichens is characterized by considerable acidity (pH value of 3. 05) and by a high percentage of organic matter (ignition loss of 40%).

By comparing the fine earth composition with the green lichens and crystalline rock

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[2] All analyses were made by L.S. Schastnaia and E.I. Mutsenek (Central Museum of Soil Science).

Table 1

General chemical characteristics of soils

Soil	Horizon and depth, cm	pH in salt extract	Exchange acidity, meq	% Humus	Adsorbed bases, meq
Profile No. 2 Peaty strongly-podzolic illuvial-ferruginous-humus sandy loam on boulder sandy loam	A_0 0— 7	2,90	5,69	Not det'd,	35,57
	A_1/A_2 8— 14	2,60	2,88	8,14	4,97
	A_2 16— 27	3,95	3,49	0.82	1,27
	B_1 33— 43	4,50	0,41	4,01	1,60
	B_2 42— 55	4,50	0,13	2,94	1,09
	C_1 61— 73	5,00	0,09	0,95	1,49
Profile No. 4 Peaty strongly-podzolic gleyed sandy loam on lacustrine-glacial fine clay loam	A_1 0— 11	2,63	13,19	Not det'd.	
	A_1/A_2 16— 20	3,78	2,94	4,28	"
	A_2 22— 32	3,85	1,26	0,73	"
	B_1 36— 53	4,04	0,85	0,41	"
	B_2 53— 63	4,10	0,65	0,38	"
	C_2 80— 90	4,13	0,67	Not det'd.	"
Profile No. 5 Sod strongly-podzolic gleyish clay loam on lacustrine glacial fine clay loam	A_0 0— 3	3,92	1,93	Not det'd.	17,70
	A_1 4— 15	3,99	1,36	4,31	4,05
	A_2B 15— 24	4,10	0,57	1,69	4,40
	B_1 24— 33	4,25	0,33	0,70	14,10
	B_1 33— 40	4,37	0,33	0,54	18,50
	B_2 42— 52	4,55	0,16	0,44	18,20
	C_1 60— 70	4,81	0,08	0,28	15,10
	C_1 80— 90	5,21	0,02	0,20	11,70
	C_2 115—120	5,24	0,03	—	8,30

Note: Comma represents decimal point.

Table 2

Total ash composition of a lichen, fine earth, and granite (% of ignited mass)

Subject of study	Ash content, %	Ignition loss	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3	K_2O	Molecular ratios			
											$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{CaO}{Al_2O_3}$
Cladonia alpestris	1,90	98,10	41,05	3,68	6,32	7,37	6,34	3,70	6,84	23,68	8,5	3,0	11,3	1,8
Granite rock	—	0,10	65,38	1,42	19,41	0,00	0,92	0,34	0,07	9,0	5,4	21,1	5,7	0,08
Fine earth of primitive soil	—	40,83	64,89	5.10	23,95	0,10	3,12	0,67	0,11	Not det'd.	4,15	7,6	4,7	0,21

Note: Comma represents decimal point.

Cladonia alpestris	SiO_2	K	P	S	Ca	Al	Mg	Fe
On the Rapakivi granite	41,9	23,6	7,4	6,8	6,3	6,3	3,7	3,6

Cladonia	SiO_2	P	S	K	Ca	Mg	Fe	Al
On sand (V. V. Ponomareva	41,6	17,5	13,1	9,9	8,9	5,6	2,4	0,6

Peltigere aftosa	SiO_2	K	Ca	P	Al	Mg	Fe	S
On crystalline schist (T. I. Evdokimova)	41,4	14,1	13,5	7,6	7,0	5,3	5,2	2,4

Collema	Ca	SiO_2	Al	K	S	P	Fe	Mg
On limestone (F. I. Levin)	44,7	13,8	9,3	5,0	4,4	4,4	4,3	3,8

Note: Comma represents decimal point.

Fig. A

composition (Table 2), we see that with the lichens the total ash content and percentage of SiO_2 and R_2O_3 is increased in the fine earth, while the percentage of all other elements is decreased; in connection with the rock we observe in the fine earth an accumulation of a series of highly available elements, such as P, S, Ca and Mg. A comparison of the ratios of $CaO:Al_2O_3$ in the lichen, rock, and fine earth shows that, despite a calcium loss from the fine earth, a large amount of calcium is still retained. In the mineralization of fine earth iron and aluminum oxide continue also to be accumulated; the ratio of $SiO_2:Al_2O_3$ drops to 4.7 which is proof of the possible synthesis of secondary clay formations under these conditions.

Thus, the initial stages of soil formation under Karelian Isthmus conditions differ essentially from the phenomena usually observed in the upper horizons of podzolic soils; consequently the lichens on the crystalline rocks are not active podzol formers. The features and properties of the fine earth examined are peculiar in many ways to the primitive soils studied in the different natural zones of the USSR (1, 3, 16, 21). The environmental conditions required for their development on rich mineral substrata under a severe rock regime unites all of these initial formations.

To explain the provincial properties of primitive soils in the Karelian Isthmus, we must conduct another series of special studies (by studying the composition of organic matter and also of different mineral fractions). These studies have been outlined in the schedule of future activities.

In turning to the results of the study of the other soil profiles, we shall first dwell on the ash content of the plant groupings in our profile. From the data on ash analyses (Tables 3, 4, 5 and Figure 2) we see that the total ash content of vegetation on the slope of the promontory gradually increases as we move from the top of the promontory to the bottom, where the ash content increases quite sharply (Profile No. 5), amounting to 10%. The mass of mineral matter involved in the biological cycle will likewise increase, although its maximum accumulation appears in Profile No. 4, where we note the greatest vegetation depth (Sphagnum). The basic vegetative types fall into two groups according to their ash composition. The first group contains the different mosses, grass vegetation and spruce needles (Profile Nos. 2, 4, 5). Their ash composition is characterized by a high silica content, the accumulation of which has an unquestionable effect on podzol formation (10, 17). Among the other elements there is a noticeable accumulation of Ca (K - in the grass vegetation), a lesser accumulation of Mg, P, S, and a relatively weak absorption of Fe and Al.

The leaves of woody species and whortleberry (Tables 3, 4, 5) constitute the second group, where the alkaline and alkali earth bases have the highest absolute percentage, while the percentage of silica is sharply less.

A high accumulation of bases in the fresh leaves is of immediate importance for the soil in Profile No. 5, where the deciduous litter forms a large part of the surface.

We shall attempt to examine the subsequent fate of ash elements in the soil formation process with regard to the decomposition character of surface vegetation and litter.

In Profile No. 2 (the peat-podzolic ferruginous-humified soil) the moss Pleorozium schreberi forms the basis of the surface cover.

The ash composition of this moss is given in Table 3.

To determine the comparative availability of the elements during moss decomposition, we shall show the ratio of the composition of the lower mineralized layer of moss to its composition of top green material (Fig. B).

Table 3

Total ash composition of vegetation and soil in Profile No. 2
(% of ignited mass)

Subject of study	Ash content, %	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3	K_2O	MnO	Molecular ratios		
											$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$
Spruce needles	3,77	53,30	3,18	—	6,31	22,54	5,56	4,77	5,56	0,16	Not det'd.		
Whortleberry	2,37	11,73	0,84	—	8,01	43,46	13,50	6,60	7,15	3,37	»	»	»
Green moss	5,37	55,12	1,49	3,35	5,02	17,50	4,09	5,02	7,63	1,67	23,3	3,3	30,3
Lower mineralized moss layer	10,69	79,14	5,98	2,52	2,06	4,30	1,68	2,80	1,90	0,18	21,3	0,8	54,1
Horizons and depth, cm													
A_0 0 – 7	—	59,0	2,20	6,70	1,16	8,70	1,22	1,90	Not det	0,42	14.0	4,6	16,3
A_1A_2 8 – 14	—	79,33	1,93	10,29	0,26	2,40	0,15	0,15	2,91	0,03	11,6	9,0	13,0
A_2 16—23	—	80,86	1,75	9,25	0,28	2,03	0,18	0,18	2,64	0,05	13,4	9,0	14,9
B_1 33—43	—	72,23	4.66	13,98	0,28	2,36	0,23	0,19	2,66	0,05	7,16	4,5	9,2
C_1 61—73	—	75,97	2,97	12,98	0,05	2,48	0,28	0,07	2,60	0,03	9,1	6,6	10,5

Note: Comma represents decimal point.

Table 4

Total ash composition of vegetation and soil in Profile No. 4
(% of ignited mass)

Subject of study	Ash content, %	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3	K_2O	Molecular ratios		
										$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$
Whortleberry	2,26	8,37	0,89	—	7,92	44,49	15,85	7,04	8,38	Not det'd.		
Green sphagnum	4,98	48,59	1,81	3,61	6,02	16,46	5,42	5,24	8,23	20,0	2,8	16,0
First mineralized layer	7,87	57,30	9,02	14,35	6,48	2,03	2,03	4,83	3,43	5,0	2,8	6,9
Second mineralized layer	8,99	50,94	16,46	18,35	5,67	1,11	0,89	4,56	1,66	3,0	1,8	4,6
Soil horizons												
A_1 6—11 *см*	—	64,08	6,02	17,26	0,67	2,93	1,65	1,20	Not det'd	5,3	5,6	6,2
A_1A_2 16—20 »	—	74,41	3,59	13,43	0,03	2,00	0,77	0,18	»	8,0	6,5	9,2
A_2 20—32 »	—	77,24	1,93	11,33	0,02	1,57	0,52	0,20	»	10,7	11,0	11,6
B_1 33—53 »	—	71,84	3,69	15,17	0,01	1,66	1,44	0,17	»	7,4	7,0	8,5
C_1 80—90 »	—	68,93	4,81	15,56	0,01	2,09	2,09	0,25	»	6,3	5,0	7,6

Note: Comma represents decimal point.

Table 5

Ash and total composition of vegetation and soil in Profile No. 5
(% of ignited mass)

Subject of study	Ash content, %	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3	K_2O	Molecular ratios SiO_2/R_2O_3	SiO_2/Al_2O_3	Al_2O_3/Fe_2O_3
Fresh leaves	6,25	7,73	0,30	—	6,13	33,87	11,53	4,81	22,19	Not det'd.		
Deciduous litter	8,99	55,45	2,23	2,89	5,68	16,25	6,34	2,23	4.12	22,0	32,8	2,0
Grass cover	9,95	51,55	0,30	0,10	3,41	10,45	8,74	3,30	16,98	Not det'd.		
Soil horizons												
A_0 0— 3 *см*	—	75,49	1,87	13,87	0,23	1,92	0,89	0,13	Not det'd.	8,9	9,6	13,0
A_1 4— 15 »	—	76,78	3,04	14,47	0,14	1,87	1,08	0,15	»	8,0	9,07	7,3
A_2B_1 15— 24 »	—	72,05	3,53	16,37	0,10	1,78	1,41	0,17	»	6,5	7,4	7,3
B_1 24— 35 »	—	66,89	4,25	22,28	0,09	1,98	2,11	0,14	»	4,7	5,3	8,0
C_1 60— 70 »	—	69,30	3,27	17,29	0,11	2,46	1,84	0,14	»	6,05	6,7	8,5
C_2 115—120 »	—	74,10	1,99	15,76	0,22	2,41	0,03	0,11	»	7,6	8,2	12,5

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ote: Comma represents decimal point.

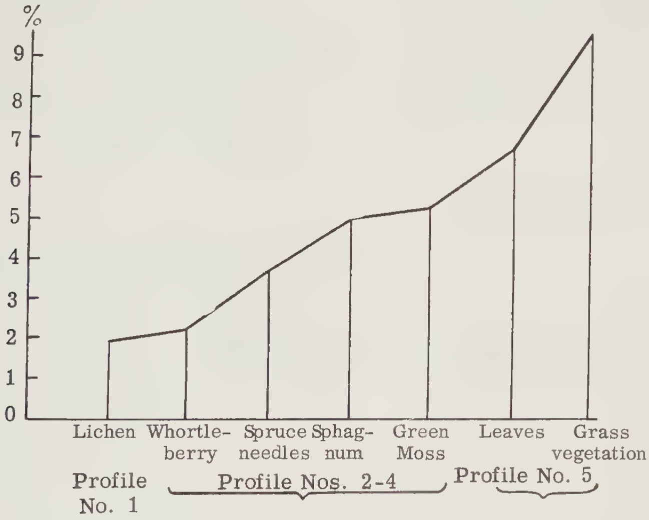

Fig. 2. - Change in the ash content of vegetation along the profile.

Fe	SiO_2	Al	S	P	Mg	Ca	K	Mn
4,0	1,40	0,80	0,50	0,40	0,40	0,30	0,20	0,10

← Accumulation

Loss →

Note: Comma represents decimal point.

Fig. B

From the series we see that Mn, K, Ca and, to a lesser extent, Mg, P and S are intensively leached from the plant residue during the decomposition process. Fe has a relatively high accumulation, while SiO_2 has less accumulation. Al is only slightly leached.

We can somewhat determine the future movement of the ash elements from the composition of the underlying litter between 0-7 cm (Table 3). As compared with moss the litter continues to be impoverished by phosphorus, sulfur and magnesium, and enriched by calcium, silica and sesquioxides. But the ratio of SiO_2:R_2O_3, which changes in the litter, shows that aluminum has the highest accumulation; the relative concentration of aluminum also increases in the underlying humus horizon, while at the same time there is an increasing loss of iron.

A further movement and accumulation of silica and sesquioxides can be seen within the soil profile (Table 3). Their molecular ratios indicate the strong podzolization of the upper soil horizons and emphasize the soil's general ferruginous-humus character, i. e., the accumulation in the illuvial horizon of mostly iron together with organic matter (see Table 1). The other ash elements, by being subjected in the soil to sudden leaching, fall into the biological cycle, while a part (as shown below) is eroded by water. Only Ca is an exception; there is a decline in its loss in the upper horizons in view of a partial transition to an adsorbed form (Table 1).

The results of the study of Profile No. 4 (the peaty-podzolic soil) are shown in Tables 1 and 4.

The organic matter in waterlogged soil is accumulated in the surface layer as a peaty moss with a high percentage of free humic acids (pH=2.6). The surface sphagnum cover is subdivided into three layers according to the degree of mineralization. Based on the ash analyses of the sphagnum we shall introduce the loss and accumulation series of the ash elements as they apply to the green cover (Fig. C).

By examining the series, we see that in the mineralizable sphagnum as well as in green moss, silica and sesquioxides are accumulated at the expense of leaching of the other elements. However, the relative loss and accumulation of all elements are considerably higher here and increase progressively as plant residue decomposes. We should point out that calcium is most readily available under these conditions; its percentage in the lower sphagnum layer with respect to the green cover is almost 15 times less (i. e., almost 4 times greater than the Ca loss from the moss cover). At the same time iron reaches a very high relative concentration in the decomposing sphagnum. The accumulation of iron here is considerably greater than in the green moss and is particularly underscored by the succeeding sharp loss of iron from the soil profile, where, besides silica, aluminum commences to assume a predominant role (Table 4, ratios of SiO_2:R_2O_3, Al_2O_3:Fe_2O_3).

The special role of iron in the soils of the Karelian Isthmus has been repeatedly discussed in literature (6, 12, 13) and the iron accumulation in the soil profile is associated with the removal and precipitation of free ulmic acids. The biogenic accumulation of iron in the profile numbers studied produces a peculiar "surface" ferrugination in these soils, which by regularly increasing from the drier soil variants to the more moist soil variants (i. e., from Profile No. 2 to 4) is apparently of great importance for the iron migration cycles in the soils. In the sandy soil series this surface ferrugination should be most significant in the peaty podzols and should be correspondingly less in the variants of podzolic illuvial-ferruginous soils. However, we should bear in mind that the biogenic accumulation of iron under the topographic conditions being studied apparently coincides with the addition of iron by surface and lateral flow. In the fall and spring the iron moves down the slope in the form of oxides or complex compounds having organic matter and partly precipitates in the upper horizons and litters. This probably explains, to some extent, the unusually high accumulation of iron in Profile No. 4. To express the amounts of iron accumulation and loss in the different soils of the Karelian Isthmus requires special study.

The final subject of our study -- the sod-podzolic clay loam -- (Profile No. 5) under a mixed grass-forest has several peculiarities (Table 1). On the surface of the soil a thin (2-3 cm) deciduous grass litter is formed; this is mineralized to a large extent. The humus is distributed more evenly along the soil profile, but with a predominant accumulation of humus in the A_1 horizon, while the reaction of all horizons is less acidic. These features are associated with the appearance and distribution in the soil of root systems of grass plants with a richer ash composition in the entire cover and with a different type of mineralization.

The results of the ash analysis and total analysis for Profile No. 5 are given in Table 5. We have already noted the peculiarities in the composition of its vegetation but wish to again point out the increased concentration of bases in it.

For comparing the composition of fresh leaves with their mineralized litter we shall introduce the following figures as the last series showing the relative loss and accumulation of the ash elements (Fig. D).

Here we already see a pattern well known to us, i. e., the relative accumulation in the

	Fe	Al	SiO_2	P	S	K	Mg	Ca
For the upper mineralized sphagnum layer	5,5	3,9	1,18	1,01	0,9	0,4	0,3	0,12
			← Accumulation		Loss →			

	Fe	Al	SiO_2	P	S	K	Mg	Ca
For the lower mineralized sphagnum layer	9,4	5,0	1,04	0,9	0,8	0,2	0,16	0,07
		← Accumulation		Loss →				

Fig. C

Fe	SiO_2	P	Mg	Ca	S	K
7,4	7,1	0,9	0,55	0,48	0,46	0,18
← Accumulation		Loss →				

Note: Comma represents decimal point.

Fig. D

mineralization process of R_2O_3 and SiO_2 during the loss of the other elements; however, the degree and order of leaching is different than in the moss cover. Potassium is the most available element. Included in the less available group are sulphur, alkali earth bases and phosphorous; at the same time the rate of magnesium and calcium loss, as compared with sphagnum, is approximately 7-8 times less, a definite neutralizing effect on the medium reaction.

The bases, which are being leached from the litter, participate chiefly in the biological cycle, although the biogenic accumulation of Ca in this soil, as compared with the preceding Profile No., is more clearly expressed. However, the basic role in the humus retention in the mineral horizons apparently belongs to iron, which is characteristic of the soils of the Karelian Isthmus (13). A total chemical analysis of this soil shows a fairly strong podzolization. This is seen in the noticeable loss of R_2O_3 and accumulation of SiO_2 not only in the podzolic but also in the upper humus horizon. In the illuvial horizon, besides a R_2O_3 accumulation, we note a somewhat increased percentage of MgO, which is probably at the expense of clay mineral formation. The ratio of SiO_2:R_2O_3 in this horizon is the smallest, as compared with other horizons, having a value of 4.7 close to the ratio found in the secondary minerals of the montmorillonite group.

In conclusion, we shall offer data on the analysis of waters collected in the spring and fall taken from the previous profiles (Table 6). We see that the water, by filtering through the

Table 6

Analysis of soil water from Profile Nos. 2, 4 and 5, mg/liter

Subject of study	Profile Nos.	Saline pH	Dry residue	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	$SO_4^=$	R_2O_3	Na + K	SiO_2
Fall collection of water	2	5,01	54,0	4,5	0,9	4,8	4,6	2.0	Traces	Not det'd	
	4	5,22	95,0	3,5	0,6	4,2	5,2	—	Traces	"	
	5	5,76	111,0	13,2	4,1	59,4	5,2	2,0	2.0	"	
Spring collection of water	2	5,35	56,0	5,0	2,0	7,3	11.4	5.8	3.5	3,5	8,5
	4	5,20	51,5	2,1	1.8	4,9	9.2	5.4	3.0	4.6	12,0
	5	6,35	462,5	47,9	20,4	222,0	117.2	12.4	Traces	53,1	34,5

Note: Comma represents decimal point.

soil mass down the slope, is gradually mineralized and accompanied by a decrease in acidity. The mineralization of waters collected in spring is noticeably higher than the fall collection and reaches a maximum (462.5 mg per liter) at the foot of the slope in Profile No. 5. The HCO_3^- is predominant in the mineral portion of the dry residue while of the cations, Ca^{++} is predominant, which is in accordance with the fact that this element is particularly available (mobile) in the moss soil litters. The $SO_4^=$ and K^+ are present in the water in lesser amounts (as active participants in the biological cycle); SiO_2 exhibits a noticeable mobility and is leached from the litter in larger amounts than R_2O_3.

CONCLUSIONS

1. The peaty-podzolic and sod-podzolic soils are predominant in the landscape of the northwest part of the Karelian Isthmus; on the crystalline rocks the initial soil-forming process is developed.

2. The first soil formation stages occur under the influence of lichens and are described by a relative accumulation in the fine earth of clay-like products and of a series of available mineral matter.

3. Calcium, intensely leached from the moss litter, acquires a peculiar mobility under the spruce-moss forests during the soil formation process. The ground waters in the spring are enriched to the greatest extent by calcium and carry it off from the slopes of the hills into the depressions where it is drawn into the more intensive biological cycle through the assistance of grass vegetation.

4. Mostly SiO_2, Al and Fe are accumulated in the vegetative layers during the decomposition process. At the same time, silica exhibits a noticeable mobility and is leached in soil waters in larger quantities than the sesquioxides.

5. Iron, on the other hand, is highly resistant to leaching. Its accumulation in the plant residue progressively increases with the increase in the degree of moisture and soil leaching. It reaches its maximum accumulation in the decomposing sphagnum of peaty podzolics, where a peculiar surface ferrugination of the soil takes place.

6. Under normal soil moisture conditions, the zone of soil ferrugination moves chiefly in the mineral horizons, and iron is the principal agent of humus matter.

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THE EFFECT OF REGULATING WATER RELATIONS OF CULTIVATED PEAT-BOG SOILS UPON THE SOIL-FORMING PROCESSES

I. N. SKRYNNIKOVA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

For devising rational methods for soil improvement and reclamation, we must determine exactly what we mean by bog soils and how these soils differ from soil-forming parent material. A unique characteristic of bog soil formation is the fact that, as new layers of peat soil develop, the lower layers become biologically less active, the number of microorganisms in these layers become sharply less, the soil formation process slows down, the soil loses its effective fertility and is transformed into a peat organogenic deposit (after Zakharov's [5] terminology). Biochemists, microbiologists (2, 10), several bog specialists (4), and hydrologists (6, 12) have come to the conclusion that we must draw a line between the upper (active) layers of peat deposit and the lower (inert) layers, or peat soil and the peat organogenic deposit.

Table 1 presents in brief outline the characteristics of peat soil and the peat organogenic deposit.

A second characteristic of bog soil formation is that excess moisture lessens to a certain extent the influence of the zonal factors in soil formation, particularly, the temperature factor.

A radical change in the soil forming process occurs in bog soils when they are cultivated and improved. A progressive accumulation of semi-decomposed organic matter occurring in natural bog soils under excess moisture conditions is replaced by the decomposition process of organic matter along with the release of the ash elements and free nitrogen and carbon compounds. The fertility of the soils to be presently improved and the time required to maintain this fertility depends upon the rate of these processes. The effect of the zonal and provincial factors, firstly, temperature, is sharply increased when the bog soils are drained. Therefore, identical methods of drainage may produce different results, for although being the same kinds of bog soils, they are located in different zones.

The practice (of many years' standing) of reclaiming bog soils in Western Europe and America for improvement purposes has brought to light the following unfavorable results from improper methods of soil improvement and reclamation: 1) a rapid destruction of the organic matter in the reclaimed bog soils (22, 23, etc.); and 2) a loss of fertility by these soils during excessive redrainage of the upper horizons. So, as Stephens (22) points out, peat depth (or thickness) decreases 7 cm annually when peat-bog soils in a tropic zone are reclaimed, 4 cm in England (after 80 years of reclamation 3. 20 m of peat layer disappeared), and 2. 3 cm in Norway. Stephens showed by laboratory experiments that 1) a loss in peat thickness occurs not so much at the expense of settling, i. e., of the physical processes, as at the expense of the decomposition of peat by aerobic microorganisms; and 2) this loss is accompanied by a liberation of a large quantity of carbon dioxide. He has also shown that the deeper the ground-water level, the more intensive the composition. Data on the intensive decrease of peat thickness are also recorded in the USSR. Thus, after 30 years of reclamation at the Peternieki experiment station (in Latvian SSR) the peat thickness decreased from 120 to 40 cm; this was also observed at the Novgorodskaya bog station. Obviously peat decomposes just as intensively in the Belorusskoe Poles'e.

The loss of soil fertility during the drainage of the upper horizons is a wide-spread phenomenon in Germany and Poland.

German soil scientists have called the process of forming these soils "Vermullung"--pulverization (16). Often such formation is caused by a longer continuous cultivation of the plowed soils and the principal feature obviously is the irreversible coagulation of the

Table 1

Difference between peat soil and peat organogenic deposits

Peat-bog soil (30-60 cm thickness)	Peat organogenic deposit (below 30-60 cm)
Effective fertility	No effective fertility
Live root system	No live root system
Many aerobic microorganisms	No aerobic microorganisms
Moisture content changes	Constant high moisture content
Level of ground waters fluctuating	Ground waters almost always present in deposit bed
Soil characterized by high water conductivity	Water conductivity negligible[a]
When the level of ground waters is periodically lowered, oxygen penetrates the soil pores	No oxygen intake
Initial process of peat formation begins	Preservation of peat occurs

[a] This feature is typical whenever the soil and deposit are similar by the botanical composition of peat formers.

organic colloids during drainage of the soil. The black surface of these soils is not covered by vegetation and, thus, is easily subjected to wind erosion (16, 19).

A rapid decrease in peat thickness and degradation or pulverization phenomena of peat soils, when improper methods of land improvement and reclamation are used, have forced soil scientists to pay particular attention to the study of the processes which occur in the improved soils of various zones when they are utilized for agricultural purposes.

The principal founders of the Russian school for soil improvement (Kostiakov, 9; Brudastov, 3, etc.), considered that the basic problem in soil improvement was not a simple flow of excess water but the regulation of the water regime of the soils and of all the soil processes. One of the principal methods used for soil improvement was damming (locking). Standard drainage specifications (depth of ground waters) were worked out for different cultivations. However, the system of soil improvement has, in recent years, increasingly pointed to only one factor -- the need of a favorable water regime for crops. The role played by soil improvement in the control and regulation of all soil processes and of the biochemical processes has been forgotten. Thus, for example, the workers of VNIIGIM (11, 18, 21, etc.) have recently proposed a new method of drainage -- deep drainage along with a lowering of the level of ground waters by 2.5-3.5 m. Lebedevich (11) and Pechkurov (14) consider the method of deep drainage as reasonable. The increase in the depth of the root system and in the thickness of the layer containing a high degree of peat decomposition is considered as a positive argument for using this method. By supporting the method of deep drainage on the basis of a study of the peat-bog soils of the Minskaia bog experiment station, Lebedevich shows, however, that an enormous excess of nitrates (up to 1,000 mg per 1 kg of dry soil) not utilized by the plant, is formed in the lower horizons of the soil during the summer months when this method of soil improvement is used. The nitrates are leached from the soil during the spring and fall with rise of ground waters (11). Thus, the result is a useless loss of soil fertility. The intensification of the nitrification and the leaching of nitrogen lead ultimately to a decrease in the total nitrogen content and in other elements. Thus, after 32 years of soil cultivation at the Minskaia station the total nitrogen content decreased 12% (from 3.63 to 3.19); the potassium content also decreased progressively despite an annual use of potassium fertilizers (13). Under normal drainage (support point of the Tsentral'naia peat-bog station) the amount of nitrogen in the soils changes very little, while the potassium content increases five to ten times. Deep drainage is now being applied at the Kirovskaia meadow-bog station and Minskaia bog station and at several points in the Meshcherskaia lowlands.

In recent years several supporters of soil improvement (8, 11) have begun to doubt the effectiveness of damming the drainage systems. However, the ineffective elements of damming, taken mostly from their data, are explained by the improper use of sluice gates. The gates that are closed at appropriate times fully provide for the maintenance of ground waters at the necessary depth. The use of damming should be corrected by controlling the groundwater level and the soil moisture. In several cases, the use of underground (mole) drainage (and, sometimes artificial rainfall) is very effective in supplementing the damming of the drainage systems.

All this shows how necessary it is to study the contemporary processes occurring in the drained and cultivated soils in order to substantiate the methods proposed for developing peat soils, their agricultural technique, and new types of crop rotations.

Since 1953 we have conducted a comprehensive study of the contemporary soil processes in the cultivated peat-bog soils of high ash content and in alluvial-bog soils at the substation of the Tsentral'naia peat-bog experiment station (TSTBOS).

We studied the dynamics of soil moisture and levels of soil-ground waters, the dynamics of oxidizing--reducing conditions, and the chemical composition of soil solutions and soil-ground waters under various weather conditions. Workers at other laboratories of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, studied the composition of organic matter and its dynamics, as well as the dynamics of the microbiological processes of soil air composition and of "the respiration" of the soils. From all the voluminous material obtained, we shall dwell on the question of the effect of normal damming on contemporary soil processes in one of the studied soil subgroups.

The region where the substation is located is on an ancient flood-plain terrace with a large preglacial stream, filled with peat deposits where the Yakhroma River has formed its present-day narrow channel. The channel region of the Yakhroma River flood-plain terrace is covered with sod-alluvial clay loam with a different degree of gleying. Farther to the south these soils are replaced by alluvial-bog (clay-peat) soils, distributed in a narrow-belt parallel to the river channel. These soils limit the effect of the river's alluvial activity. The remaining portion of the ancient flood-plain terrace is covered with humic-peat ferruginous soils on grass-scrub-woody peat in the central section of the ancient flood-plain and with humic-peat carbonate ferruginous soils on grass-Hypnum peat in areas adjacent to the continental shore. Of great importance in the formation of alluvial-bog lowland-bog soils of the station are the ground waters under pressure, which flow from the main shore. The soils of the station are improved by combining closed and open drains. The drainage network has now been dammed. The ground-water level is kept at a depth of 80-100 cm.

The improvement and cultivation of soils of the station over a period of 30-33 years have led to the formation at the spot of former bog soils, of new soils with deep plowed layers (25-30 cm), strongly humified, of excellent structure, with a high degree of peat decomposition, a lowered water-holding capacity, and an excellent aeration. Perennial grass cultivation has led to the rejuvenation of the organic matter in these layers. Only few small fragments of wood bark, bush twigs (or branches), etc., remind us that the plowed layers had been peat.

The subsoils are characterized by a lower degree of peat decomposition, the presence of a large number of well-formed crop residue -- peat formers. These subsoils differ very sharply in their total chemical analysis and moisture properties (see Tables 2 and 3). The plowed layers differ from the subsoil by their considerably higher ash content.

Mineral elements in the plowed layers accumulate in all the soils of the station during peat decomposition under the influence of soil improvement and cultivation. But, more important are the other causes of the accumulation of the mineral elements. In the alluvial-bog soils the boundary of the plowed layers coincides with the boundary of former silting; therefore, the former alluvial activity of the river is the principal cause of mineral accumulation in this soil. The predominant elements are SiO_2, Al_2O_3 and Fe_2O_3. In the soils of the central part of the valley and in sections near the main shore the ground waters are an important cause of the accumulation of mineral elements in the plowed layers. Mineral elements accumulate here during the evaporation of the moisture rising in capillary form. The Fe, P and partly Ca[1] are thus accumulated in the plowed layers of the central part of the valley; in the areas adjacent to the main shore, Ca is chiefly accumulated. The precipitation from the solutions of mineral elements in the upper layers occurs to a certain extent before soil improvement and drainage, but these processes are especially intensified when the bog soils are reclaimed. Whatever the source for enriching the plowed layers of the soil by mineral elements, the actual enrichment plays an enormous positive role in increasing the fertility of peat-bog soils, because at the same time the humified organic compounds are more stable and the organomineral compounds and excellent soil structure are formed.

The plowed layers of the soils have more favorable water-physical properties than the subsoil; they have a higher bulk density and specific gravity, and a lower saturation minimum moisture capacity and wilting moisture (Table 3).

Soil improvement decreases the basic difference -- the various degrees of moisture --

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[1] The presence of considerable quantities of SiO_2, Al_2O_3 and, partly Fe_2O_3 in the ash content of these soils is explained by the presence of silt-like particles of diluvial or aeolic origin.

Table 2

Total chemical analysis of the alluvial-bog and peat-bog soils of high ash content

Profile No., soil	Depth, cm	Hygroscopic water	Ash content	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	TiO_2	CaO	MgO	MnO	K_2O	Na_2O	Total
		%		% of absolutely dry soil										
54 Alluvial-bog (clay-peat)	0–10	10,03	52,15	32,38	9,94	8,99	0,62	0,03	2,27	0,96	0,11	1,99	0,59	58,31
	10–20	10,23	51,62	32,00	9,13	9,37	0,64	0,03	2,51	0,93	0,13	1,80	0,58	57,55
	22–29	9,84	51,92	32,28	9,32	9,39	0,48	0,03	2,31	1,03	0,12	1,65	0,65	57,72
	60–70	14,50	13,76	4,61	1,93	3,41	0,29	0,006	4,02	0,49	0,27	1,09	0,25	16,78
56 Humic-peat ferruginous	0–10	14,47	35,39	15,71	3,55	13,64	3,04	0,01	3,34	0,43	0,08	0,75	0,44	41,66
	10–20	15,04	34,40	12,76	2,48	15,16	4,02	0,01	3,82	0,42	0,07	0,52	0,38	40,59
	30–40	13,77	9,72	2,07	1,42	3,14	0,36	**Traces**	2,91	0,26	**Traces**	0,71	0,46	11,31
	60–70	14,07	9,76	2,60	1,36	2,35	0,27	"	3,00	0,41	"	0,87	0,30	11,62
58 Humic-peat ferruginous-carbonate	0–10	12,32	33,09	14,00	2,01	8,70	1,05	**Traces**	10,47	0,42	0,12	0,38	0,11	38,03
	16–20	11,38	33,26	14,48	1,97	9,32	1,03	"	9,64	0,42	0,11	0,95	0,58	39,10
	30–40	14,13	7,20	0,92	0,68	1,28	0,24	"	3,99	0,26	0,02	1,13	0,43	9,52
	60–70	12,11	13,96	0,64	0,54	1,16	0,18	"	11,26	0,18	0,04	0,19	0,08	14,68

Note: Comma represents decimal point.

among the natural lowland bog soils of the Yakhroma River valley. Continuous cultivation of perennial grasses eliminates somewhat the second difference which is a result of the first. This difference is the varying nature of peat in the soils which have been found beneath moss, shrub and meadow bog vegetation before improvement. However, these differences still remain at the present stage of cultivation and, consequently, for soils of the different valley regions, we must employ a different agricultural technique that has been worked out by workers of the substation of TSTBOS (20).

We obtained very interesting data on the moisture regime in the cultivated bog soils of the station. When the gates are operating normally, the moisture chronoisopleths indicate the presence of a large difference in the water regime of plowed and subsoil layers (Figure 1). In the vegetative period the moisture of plowed layers in the soils of the channel area and of the central valley sections are almost always somewhat lower than the minimum moisture capacity, while in the driest periods the moisture is lowered almost to the wilting moisture. The moisture of plowed layers changes with precipitation, but does not depend upon the depth of ground waters. Moisture regime of subsoils differs sharply. Their moisture is above the minimum moisture capacity. The subsoils are always found in a capillary zone when the ground waters are 70-100 cm deep. The lower limit of the plowed layer under cultivation and under perennial grasses acts as a boundary for the capillary rise of water. In our opinion, this type of water regime is the most favorable both for the growth of crops and for the biochemical processes in the soil. The root system of crops in plowed layers is always in a sufficiently aerated medium; at the same time, whenever there is a lack of moisture in the plowed layer the crop may obtain moisture from the subsoil which is always sufficiently moist.

A study of the oxidizing-reducing conditions also shows a great difference between the plowed and subsoil layers. Judging by the data on the determination of the oxidizing-reducing potential, the plowed-layer of the soils are continually found under aerobic conditions, when the level of the ground waters is normal, in the subsoil -- in the zone of capillary supply particularly, in the lower area adjacent to the table -- the anaerobic conditions (Figure 2) dominate a large part of the vegetation period. Consequently, under such a water regime, mainly the upper part of the soil profile -- the plowed layer and the layer in transition to the subsoil of a thickness as much as 40 cm is biochemically active. The decomposition processes occur very weakly in the lower part of the profile because of a lack of oxygen. The morphological structure of the profile and the

Table 3

The water-physical properties of alluvial-bog soils and peat-bog soils of high ash content

Profile No., Soil	Depth, cm	Bulk density	Specific gravity	Saturation moisture capacity	Minimum moisture capacity	Wilting moisture
		%		% of absolutely dry soil		
54 Alluvial-bog (clay-peat)	0 —10	0,35	2,11	238	221	51
	10 20	0,38	2,17	217	215	79
	22—29	0,30	2,12	286	268	96
	60—70	0,15	1,68	585	not det'd.	193
56 Humic-peat ferrugionous	0 —10	0,22	1,99	404	223	74
	10—20	0,25	1,96	345	208	89
	30—40	0,15	1,71	608	375	171
	60—70	0,13	1,60	678	not det'd.	354
58 Humic-peat ferruginous-carbonate	0 —10	0,26	2,09	337	242	79
	10–20	0,28	2,09	309	231	83
	30—40	0,15	1,74	609	535	172
	60—70	0,17	1,86	534	463	356

Note: Comma represents decimal point.

direct determinations of the dynamics of the content of different chemical compounds in the soils bear this out.

Figure 3 shows the dynamics of the chemical elements in a soil solution of humic-peat ferruginous soil on grass-woody peat in the driest vegetation period (1954) when the ground-water level dropped to 120 cm. Under these conditions the mineralization processes of the organic residue were intensive in the plowed layers and the concentration of mineral elements in them was high. At the same time only in June was a flourish of the biochemical processes in the lower layers observed. These processes obviously had the character of an incomplete decomposition, since in the soil solution of the lower layers there was a considerable number of organic compounds with a low concentration of mineral compounds. Under ordinary conditions, when the ground waters were at a depth of 80-100 cm and the entire mass of the subsoil layer was found in a zone of capillary moisture supply the processes of peat decomposition in the layer were even more suppressed.

Table 4 presents data on the nitrate content in a soil solution of humic-peat ferruginous soil beneath perennial grasses over a three year period of study. The low concentration of nitrates in a solution of the upper soil horizons is explained by an intensive absorption by their grassy vegetation.[2] In the lower horizons this phenomenon is associated with a suppression of the biochemical processes under a given type of water regime in these soils. As we noted above, a large quantity of nitrates, not utilized by crops, is observed in Belorussia during deep drainage and also in the lower horizons of peat-bog soils, which is proof of the intensive decomposition processes in the subsoil during deep drainage.

Of interest is the behavior in the soil air and in the soil solutions of carbon dioxide, a product of the mineralization of organic matter and of the active nature of the root systems. From Ignat'evd's (7) data, in the soil air of the lower horizons of deeply drained peat-bog soils as much as 8% (percent by volume) of carbon dioxide may be accumulated.

An accumulation of such a large amount of carbon dioxide in soils with a normal level of ground waters and excellent aeration of the plowed layers is rare and is associated with a sudden deterioration of aeration in the upper horizons. A high partial pressure of carbon dioxide in soil air is the cause of its high concentration in the soil solution. At the same time the carbonates in carbonate peat

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[2] The nitrates, formed by the decomposition process of plant residue and peat in the plowed layer are sufficient for guaranteeing a yield of perennial grasses, at 80-100 cntr per ha (20).

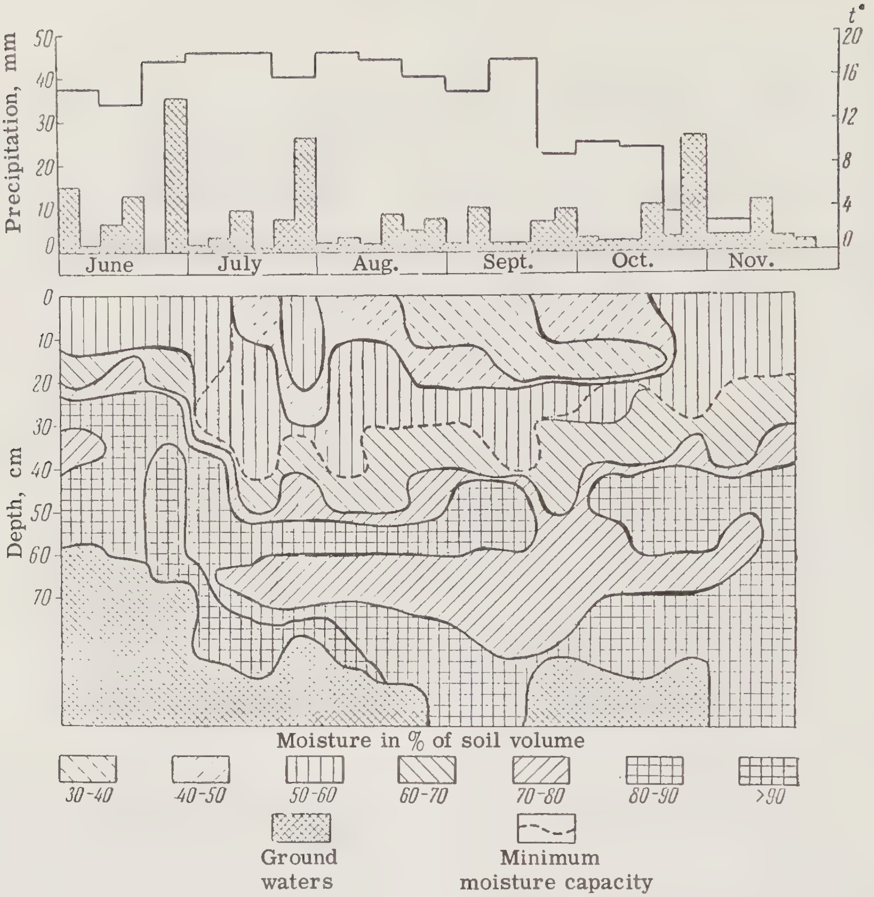

Fig. 1. - Precipitation, air temperature and moisture of humic-peat ferruginous cultivated soil (Profile No. 56, 1956).

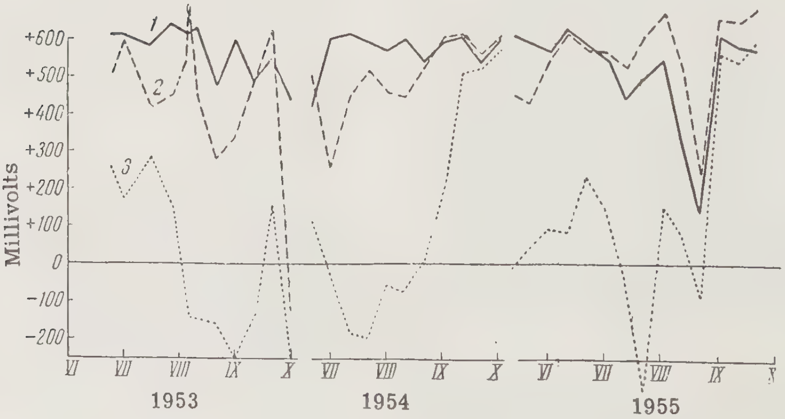

Fig. 2. - Dynamics of the oxidizing-reducing potential in the humic-peat-ferruginous cultivated soil (Profile No. 56).

1 - 0-5 cm; 2 - 25-30 cm; 3 - 65-70 cm

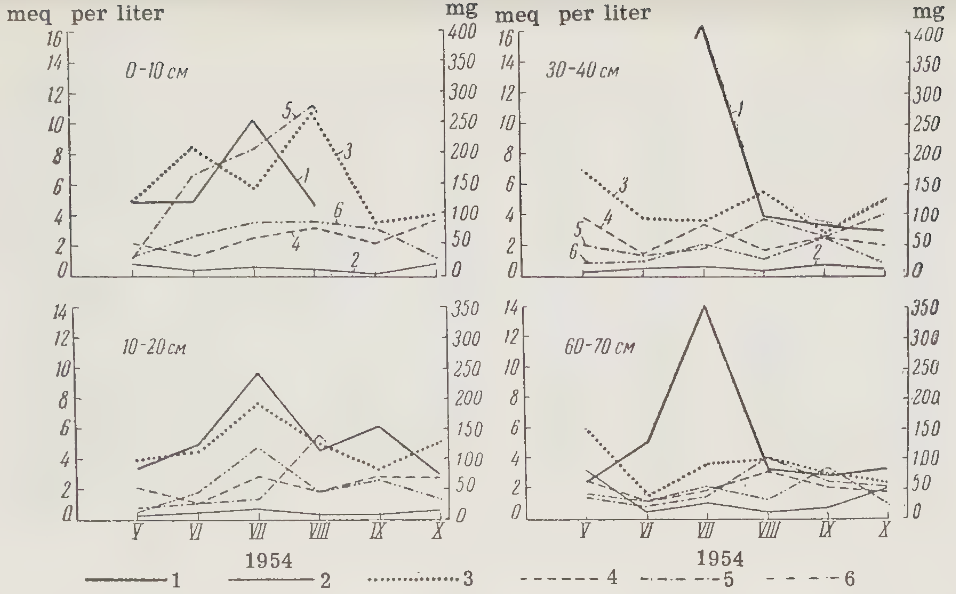

Fig. 3. - Dynamics of the chemical composition of soil solutions of humic-peat-ferruginous cultivated soil (Profile No. 56).

1 - Organic matter in meq per liter; 2 - HCO_3; 3 - Ca; 4 - Mg; 5 - Cl; 6 - SO_4 in meq per liter.

Table 4

Dynamics of the nitrates in soil solutions of high ash content peat-bog soils (meq per liter)

Profile No. Type of Soil	Depth, cm	1953					1954						1955								
		June	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
56 Humic-peat ferruginous	0—10	0,33	0,06	—	0,12	none	0,03	0,17	none	traces	none	0,18	traces	traces	0,07	0,18	none	none	none	none
	10—20	0,36	0,09	0,10	0,17	"	0,03	0,41	0,18	0,05	"	0,16	0,05	0,16	1,10	0,45	"	"	"	traces
	30—40	0,45	0,14	0,35	0,16	"	0,06	0,19	0,17	0,08	"	traces	0,32	0,32	0,13	0,25	"	0,08	0,10	"
	60—70	not det.	traces	none	0,08	0,10	traces	traces	traces	traces	"	"	traces	none	0,02	traces	"	0,08	0,09	none

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Note: Comma represents decimal point.

dissolve and the calcium, magnesium and potassium ions are exchanged from the soil adsorption complex of non-carbonate soils; this has been discussed in an earlier published article (7).

Thus, when the level of ground waters is 80-100 cm in the improved peat-bog soils, a two-layered soil profile is formed, during which only the plowed layers are encompassed by intensive biochemical processes. In addition, we have not only developed favorable conditions for the growth of cultivated crops and guaranteed a high crop yield at present, but we have preserved and even increased the potential fertility of peat-bog soils.

CONCLUSIONS

1. The purpose of the different methods used on bog soils should be not only to create favorable conditions in the water regime and to guarantee high agricultural crop yields at present, but also to provide for a progressive increase in effective and potential fertility which may be achieved by controlling the soil, and firstly, the biochemical processes. Therefore, the study of the soil processes should be based on working out methods for soil improvement, agricultural techniques and a crop rotation system.

2. An intensification of the rate of the biochemical processes in the lower horizons of the soils leads to a useless loss and sometimes to a complete loss of soil fertility, because of excessive drainage. Therefore, deep drainage of bog soils in the forested steppe and southern portions of the forest zone should be forbidden.

3. The most favorable type of water regime and type of biochemical processes (as applied to the central regions of the Soviet Union) result when the ground waters are not more than 80-100 cm deep.

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EFFECT OF IRRIGATION ON THE NUTRIENT REGIME OF CISCAUCASIAN CHERNOZEMS

N. I. BOLOTINA, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The Ciscaucasian calcareous and leached chernozems are characterized by high fertility; they contain abundant supplies of phosphorous, potassium, and nitrogen, but their fertility is exhibited only if sufficient moisture is in the soil.

Construction of the Tsimlyan and Vesselov reservoirs and systems of canals led to the formation of new irrigated regions, especially in Rostov Oblast' where irrigation was introduced in 1951 and 1952 in the western part of the Don-Manych watershed and on the second terrace of the lower Don. Further development of agriculture in these regions is inseparable from the rational use of water, soil nutrients, and fertilizer.

Thus, it is necessary to ascertain to what extent soil nutrients are mobilized by irrigation, when fertilizers may be omitted, and when it is profitable to use them with irrigation.

For this purpose observations were made by agricultural chemistry section of the V. V. Dokuchayev Soil Institute and experiments established on collective farms of Bataisk region, Rostov Oblast' (Koisug village and Stalin farm), irrigated since 1952, and the Bataisk state vegetable farm, where irrigation has been used since 1938. On the collective farm, experiments were devised to study the effect of mineral fertilizers with irrigation on yields of winter and spring wheat, potatoes, corn, and alfalfa. The field experiment was combined with a study of the effects of irrigation on the physical and chemical properties of the soil. The following systems of irrigation were used: on winter wheat a pre-irrigation of 1200 m^3/ha before seeding and a vegetative irrigation of 500 m^3 in May; two vegetative irrigations of 600 m^3 in early May and early June; on spring wheat, one irrigation of 650 m^3 in late May; on potatoes with spring planting, two irrigations of 600-650 m^3 each; and on corn, two irrigations, 650 m^3 in mid-June and 800 m^3 in mid-July.

A vast literature is devoted to questions of irrigated agriculture, but only a few works contain material on the effects of irrigation on soil properties. According to Zhorikov's investigations (4) on Central Asian sierozems, long continued irrigation causes profound changes in texture and composition of soils. Thus, irrigation increases the clay content at a depth of one to two meters because of the deposition of clay particles from the irrigation water. The content of easily soluble salts decreases noticeably while that of exchangeable calcium increased.

The effect of irrigation on the nutrient regime of sierozems is most sharply expressec in the nitrate content (3). In the first five or six days after irrigation, a sharp reduction is noted in its content in the upper horizons and a downward movement to one meter, especially in June and July, when the soil contains much nitrate. By fall nitrates return to the soil surface, where, in addition, there is an increase in nitrification. Irrigation methods hav a great effect on nitrification intensity. Flood irrigation inhabits the process, infiltrating irrigation encourages it (2, 6).

Under irrigation the supply of easily soluble phosphates in sierozems decreases and the amount of difficultly soluble forms increases because of the increased concentration of Ca^{++} in the soil solution (4).

On light chestnut soils irrigation leads to some reduction in the amount of humus and eluviation of colloidal particles to the lower horizons (8). In clean fallow the nitrate content in the upper horizons decreases after each irrigation as a result of movement into the lower horizons, and the reverse movement occurs as the soil dries out. In cropped soils irrigation hinders nitrification to such an exter hat even after harvest the amount of nitrate loes not return to its previous level (7).

On dark chestnut soils of Kherson and Saratov Oblasts' and on ordinary chernozems of Stalingrad Oblast', according to the investigations of Antipov-Karatayev and Filippov (1), continuous irrigation in grassland-crop rotations does not show deleterious effects on the humus content exchangeable bases, and available phosphorous and potassium in the soil.

On thick chernozems of Kursk Oblast', according to Zhukov (5), irrigation causes the movement of nitrates from the upper layers into the lower. The rate and depth of leaching increases with the rate of irrigation. The content of available phosphorous changes very little under irrigation, but that of available potassium increases owing to the shift of difficultly soluble compounds into more soluble forms resulting from increased moisture (10).

In the experiments of Prostakov (9) on Ciscaucasian chernozems (Azov), two years of irrigation did not affect the humus content of the soil. On fallow or under winter, spring and cultivated crops in nine-year rotation (four years of alfalfa), irrigation decreased the nitrate content of the soil because of poorer aeration and leaching of nitrates. After irrigation at optimal rates, nitrate losses are made up by the following irrigation. With irrigation a decrease in amount of water soluble phosphorous compounds was noted under all crops.

Effect of Irrigation on the Physical Properties of Ciscaucasian Chernozems

Observations showed compaction of the 0-10 cm layer of soil as a result of irrigation. After two years of irrigation the bulk density of calcareous chernozems increased from 1.13 to 1.27 (average of 72 determinations), and that of leached chernozems from 1.22 to 1.35 (average of 36). With many years of irrigation, the bulk density of the arable layer (0-20 cm) increased to 1.37. Compaction of the upper layer decreases water entry into the soil. After prolonged irrigation the rate of water entry (measured by flooding quadrats on the soil surface) under barley stubble was 0.8 mm of water/min after two hours of observation; after two or three years of irrigation on calcareous chernozem, similar measurements (under wheat stubble) showed 1.5 - 3.8 mm, and on leached chernozem, 1.25-1.5 mm. Irrigation also changed the structure of the surface layers somewhat, decreasing the amount of water stable aggregates. Thus, the content of water stable aggregates (by Savvinov's method) larger than 0.25 mm in diameter in grain fields without irrigation amounted to 44%-57% in the 0-20 cm layer and 70% in the 20-40 cm layer; after two years of irrigation the corresponding figures were 34%-43% and 48%-49%, and after continuous irrigation 28% and 54%. In soil under grass, the content of water stable aggregates larger than 0.25 mm was somewhat higher than under grain crops: 57% in the 0-20 cm and 77% in the 40-60 cm layer without irrigation, 52% and 70%, respectively, with irrigation. Thus, there is some deterioration of the physical properties of soils after irrigation.

Nitrogen Regime

The Ciscaucasian chernozems in the area of investigation contain the following amounts of humus and nitrogen (Table 1).

We traced the effect of continuous irrigation on the humus content of a calcareous chernozem (Table 2).

The data of Table 2 show that irrigation under grassland-crop rotation on the Bataisk state vegetable farm scarcely changed the humus content of the soil; only that part under alfalfa showed increased humus with 15 years of irrigation. The accumulated organic matter from alfalfa decomposes rapidly under subsequent irrigated crops, and after five years the humus content is near that in soils without continuous irrigation or without proper grassland-crop rotation.

The solubility of soil nitrogen (judging from the percentage of it that is hydrolyzable, shown in Table 1) in Ciscaucasian chernozems is appreciable, especially in leached chernozems.

The content of hydrolyzable nitrogen decreases during the growing season on both irrigated and non-irrigated soils. Thus, in the plowed layer of newly irrigated chernozems under spring wheat there was 60 mg hydrolyzable nitrogen in the spring and 46 mg/kg of soil in the fall, under winter wheat following grain 45 and 34 mg/kg, under winter wheat following sod 113 and 52 mg/kg, in continuously irrigated soil under barley 55 and 31 mg/kg. In the same soil the content of hydrolyzable nitrogen varies with different crops in the rotation. For example, in the spring the hydrolyzable nitrogen content in the plowed layer under fallow was 100 mg/kg of soil, under winter wheat following fallow 70-90, under corn 50-70, under spring what 50-60, under winter wheat following grain 45-55 mg/kg. This distribution of hydrolyzable nitrogen evidently varies with the structure of the plowed layer and its degree of aeration. We present data below on variations in nitrate content of the soil under winter wheat (Table 3) and corn (Table 5).

Table 1

Humus and nitrogen contents in chernozems of Bataisk region, Rostov Oblast'

Depth, cm	% in soil dried at 105°C		Hydrolyzable nitrogen	
	Humus	Total nitrogen	mg/kg of dry soil	Total N %
		Calcareous chernozem		
0–30	3.8±0.1	0.21±0.02	51±3.2	2.4
20–40	3.5±0.1	0.17±0.01	48±3.8	2.8
40–60	2.9±0.1	0.14±0.01	32±3.0	2.3
60–80	1.9±0.1	0.12[a]	37±8.0	3.0
80–100	1.4±0.1	—	10±0.8	—
110–130	0.8±0.2	0.06[a]	—	—
		Leached chernozem		
0–20	4.7±0.2	0.25±0.1	77±8.9	3.1
20–40	4.3±0.2	0.18±0.02	68±9.1	3.5
40–60	3.5±0.2	0.17[a]	56±6.3	3.2
60–80	3.1±0.3	—	48±6.3	4.0
80–100	2.6±0.2	0.12[a]	50±0.6	4.2
100–120	1.5[a]	0.07[a]	28[a]	3.9

[a] single determination

Table 2

The effect of irrigation on the humus content (in %) in calcareous chernozem under various crops (average of 9-16 samples)

Depth, cm	Stipa steppe	Second year alfalfa			Winter wheat			Potatoes 2 years irrigation	Barley 15 years irrigation
					Without irrigation		2 years irrigation following grain		
		Without irrigation	2 years irrigation	15 yrs. irrigation	Following fallow and cultivated crops	Following sod			
0–20	5.0	3.7	3.6	4.6	3.8	3.9	3.8	3.5	3.5
20–40	3.8	3.3	3.3	3.8	3.5	3.6	3.6	3.5	3.3
40–60	3.2	2.6	3.1	2.8	2.8	2.8	2.9	3.0	2.8

Nitrification and the use of nitrates by plants are inseparably dissociated with the soil moisture content. Soil moisture on the experimental areas, except for winter wheat following fallow, was insufficient without irrigation in the years of the experiments. On the non-irrigated soil the supply of water was appreciable only in April; 6%-8% available moisture (per wt. of soil) in the plowed layer and about 14% in the 20-60 cm layer. The water supply decreased 50% in May, and the plowed layer was almost dry in June, while available moisture was only 2%-3% in the subsoil to 60 cm. Irrigation maintained the available moisture supply at a level of 8%-10% to a depth of one meter during the summer months.

Insufficient soil moisture limited nitrate uptake by plants. Table 3 shows that under winter wheat following sod or fallow, considerable nitrate was found in the subsoil on non-irrigated plots, whereas on irrigated

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[1] The average precipitation in the Bataisk region from April through June over a period of years is 202 mm. In 1954, 107 mm fell in this period, in 1955, 77 mm. The drought brought a large response to irrigation.

Table 3

Variations in nitrate nitrogen content in the soil under winter wheat on Ciscaucasian chernozems (mg N/kg of soil)

Preceding crop	Depth, cm	Sept. before seeding wheat		April		May		June		July	
		Irr.	N. Irr.	Irr.	N. Irr.	Irr.	N. Irr.	Irr.	N. Irr.	Irr.	N. Irr.
		Calcareous chernozem									
Winter wheat, after wheat, 1955	0–20	10	14	3	2	3	2	2	Trace	2	3
	20–40	3	8	2	2	2	2	Trace	2	Trace	Trace
	40–60	None	3	Trace	2	Trace	2	"	2	"	2
	60–80	--	--	None	4	"	Trace	2	Trace	"	Trace
	80–100	--	--	"	4	"	4	3	"	2	"
Alfalfa, 1955	0–20	22	33	30	3	2	5	4	5	4	5
	20–40	4	4	14	11	3	5	3	2	2	9
	40–60	3	4	24	29	3	16	4	14	2	25
	60–80	--	--	15	11	3	14	3	14	2	17
	80–100	--	--	2	16	3	7	Trace	6	2	5
Fallow, 1954	0–20	--	--	--	38	--	6	--	4	--	8
	20–40	--	--	--	26	--	25	--	17	--	21
	40–60	--	--	--	19	--	20	--	9	--	11
		Leached chernozem									
Fallow, 1954	0–20	28	55	7	25	Trace	5	Trace	3	9	13
	20–40	16	22	17	35	3	13	"	7	2	5
	40–60	8	19	8	6	6	9	None	4	None	5

Note: Irr. -- with a charging irrigation, N. Irr. -- without irrigation.

plots the plants used almost all of the nitrate from these horizons. Under winter wheat following grain very little available nitrogen was found in the soil before or during the growth period. Grain crops had been sown continuously on this field during the last seven or eight years. This apparently explains the low content of hydrolyzable nitrogen in the soil (45 against 60-113 mg N/kg of soil on other fields) and its slow rate of nitrification.

In continuously-cropped soils little or no nitrate is usually found. Whether this is due to weak nitrification under plants or to immediate absorption of the nitrates formed is not clear. The question was investigated by observing changes in nitrate nitrogen under winter wheat and on plots from which it had been removed (the other conditions were uniform). The wheat plants were carefully removed from plots six meters square during tillering or heading. The structure of the plowed layer was practically undisturbed, and thus retained the same conditions for nitrification as under the plants. At the end of each month, the moisture and nitrate contents of the soils of plots with and without plants were determined. The nitrate content was always higher on plots without plants. The amount of nitrates formed by nitrification in the soil under plants may be judged by differences in the nitrate content of comparable plots. The validity of this comparison is shown by the fact that after harvest the soils with and without plants had practically the same amounts of nitrates (see Table 4).

A large factor in nitrification must have been the different moisture content of the two plots, which was unavoidable since in one case moisture was used by the plants, while in the other, with no plants, this was excluded. Differences in moisture of soil (up to one meter deep) were not observed on the plots being compared during the first two or three weeks after removal of the plants or the first eight to ten days after irrigation, and at all times in the plowed layer. During the growing season moisture differences in the plowed layer averaged 30-40 m^3/ha on irrigated plots, 30-70 m^3 on non-irrigated plots with variations at different times of from 0-112 m^3. Below the plowed layer differences in water content on plots with and without plants averaged 40-60 m^3/ha with irrigation, 100-150 m^3 without irrigation, with variations of from 0-300 m^3/ha. When the grain was turning, the moisture content in the subsoil (to one meter in depth) without plants was even greater in comparison with that under wheat. Differences averaged 120-220 m^3, with variations to 340 m^3/ha.

In view of these differences in soil moisture

Table 4

Nitrate nitrogen content in the soil under winter wheat
(according to differences in its contents on plots with and without plants, kg/ha)

Soil layer, cm	Clean fallow			Plots with plants removed											
				in April						in May					
	April	May	June	April	May		June		Af. Har.	May		June		Af. Har.	
					N.Irr.	Irr.	N.Irr.	Irr.	Irr.	N.Irr.	Irr.	N.Irr.	Irr.	N.Irr.	Irr.
Calcareous chernozem. Grain crop preceding. Without charging irrigation. Experiment 1															
0 - 60	--	--	--	34	63	34	67	39	16	23	44	30	40	--	7
With charging irrigation. Experiment 2															
0 - 100	53	93	105	47	58	36	57	50	--	--	--	--	--	--	--
Leached chernozem. Fallow preceding. Without charging irrigation. Experiment 3															
0 - 60	140	165	Irr. 108	40	62	--	--	59	30	40	--	--	35	--	6
With charging irrigation. Experiment 4															
0 - 60	60	170	205	79	110	--	134	--	N.Irr. 24	56	--	33	--	23	--

Comment. Analyses by layers 0-10, 10 - 20, 20 - 40, etc., were summed for the entire layers 0 - 60 or 0 - 100 cm.

Note: N.Irr. -- without irrigation, Irr. -- with irrigation, Af. Har. -- after harvest.

content, with and without plants, nitrification under wheat must be studied by observations over one or two month periods after removal of the plants from the plots, when the air-water regime in the soil is fairly stable. Data on nitrification in soils under winter wheat are presented in Table 4. For comparison, data are also presented on changes in nitrates in clean fallowed soil at the same time as the experiment. The data in Table 4 show that nitrification is two or three times greater under fallow than under winter wheat. On calcareous chernozem the difference in nitrate content of the 0-60 cm soil depth with and without plants shows that the soil under wheat formed 34 kg of nitrate nitrogen/ha in April, 23 in May, 30 in June without irrigation, 34-44 in May and 40 in June with irrigation (Experiment 1). In Experiment 2 with irrigation there 47 kg nitrate nitrogen/ha was observed in April, about 60 in May, and about 50 kg in June in the 0-100 cm soil depth under wheat.

On leached chernozem with a higher content of humus and hydrolyzable nitrogen (see Table 1), nitrification under winter wheat following fallow proceeded faster than in the experiments on calcareous chernozem following grain. In Experiment 3 without pre-irrigation, 40 kg of nitrate nitrogen/ha formed in April, and the same in May and June; in Experiment 4 with pre-irrigation, 79 formed in April, 56 in May, and 33 kg/ha in June.

Irrigation has the following effects on nitrification. On plots without plants, especially after clean fallow, the nitrate content decreases markedly after irrigation. For example, on clean fallow with a fall pre-irrigation, the nitrate nitrogen content the following spring was 60 kg/ha, whereas on the same fallow without pre-irrigation it was 140 kg/ha. On clean fallow with vegetative irrigation in June, the content decreased 165 kg/ha, and irrigation in May, 108 kg/ha. These decreases in nitrate are explained partly by leaching and partly by slower nitrification from poorer air-water conditions after irrigation. Irrigated winter wheat did not cause less nitrate to be formed in the soil under the plants. On the contrary, an increase was observed relative to non-irrigated plots, for example, in Experiment 1 from 23-30 to 40-44 kg of nitrate nitrogen/ha.

Under cultivated crops, owing to repeated inter-row tillage, nitrification proceeds more energetically and more nitrates are observed during the growing period than under broadcast sowing of grain crops. We present by way of

Table 5

Nitrate nitrogen content in the soil under corn on Ciscaucasian chernozems (mg N/kg of soil)

Crop	Depth, cm	April	May		June		July		August
		N.Irr.	Irr.	N.Irr.	Irr.	N.Irr.	Irr.	N.Irr.	Irrigated
				Calcareous chernozem					
									August 9
Corn following spring wheat	0–20	6	16	21	14	16	9	23	4
	20–40	4	15	12	6	13	2	15	3
	40–60	8	8	30	11	17	5	17	5
	60–80	10	19	20	16	11	8	6	3
	80–100	6	--	--	7	5	8	6	3
				Leached chernozem					
									August 26
Corn following potatoes	0–20	—	—	—	24	21	20	—	7
	20–40	—	—	—	32	21	17	—	7
	40–60	—	—	—	39	32	24	—	5
	60–80	—	—	—	25	20	14	—	8
	80–100	—	—	—	15	12	9	—	6

Note: N. Irr. — without irrigation; Irr. — with irrigation.

illustration data on nitrate content of the soil under corn (Table 5), consisting of an average of two determinations per month. On calcareous chernozems more nitrates are found under non-irrigated corn than under irrigation. Insufficient moisture limits the uptake of nitrogen by plants. With irrigated corn there is some leaching of nitrates from the surface into the lower layers.

Nitrification in the soil under corn is quite intense. This becomes apparent by summing the amounts of nitrate nitrogen in the humus layer of soil not used by corn and that accumulated by the plants during the summer growth period -- June and July (Table 6).

Table 6

Nitrate nitrogen content in the soil under corn during June and July, kg/ha

Depth, cm	Calcareous chernozem		Leached chernozem
	w/out Irr.	with irrigation	
0–20	45	26	44
20–40	35	10	58
40–60	40	19	72
60–80	18	29	48
80–100	14	19	31
0–100	152	103	253

By August the top portion of irrigated corn, with a total dry weight of 74 cntr/ha and nitrogen content of 1. 93%, had taken up 143 kg of nitrogen from the calcareous chernozem, and with 95 ha of dry weight, 184 kg of nitrogen from the leached chernozem. Thus, without considering the nitrogen content of underground plant parts, nitrification in the one-meter layer under irrigated corn amounted to about 246 kg N/ha on the calcareous chernozem and 437 kg/ha on the leached chernozem.

By increasing the yield of corn irrigation mobilizes nitrogen in the soil. Without irrigation, a corn yield of 73 cntr dry wt/ha, harvested at full maturity removed 88 kg of nitrogen, but with irrigation a yield of 20 cntr/ha removed 239 kg of nitrogen.

The sufficiency of available nitrogen in the soil is customarily estimated by the content of hydrolyzable nitrogen determined according to the method of I. V. Tyurin and M. M. Kononova. We do not have enough field experiments on the Ciscaucasian chernozems to determine critical levels. Nevertheless our yield data from field experiments with nitrogen fertilizers and data on the dynamics of nitrates allow some consideration of this question for calcareous chernozems. In Table 7 the yield increases from nitrogen fertilizer in field experiments are compared with the hydrolyzable nitrogen content of the soil.

As these data show, irrigation doubled the yield of crops without fertilizer. With 30-60 mg of hydrolyzable nitrogen/kg of soil, small amounts of nitrogen fertilizer (17 kg

Table 7

Crop yields and content of hydrolyzable nitrogen in the soil in field experiments on calcareous chernozem

Crop	Year	Preceding Crop	Yield of grain or tubers, cntr/ha			Nitrogen fertilizer applied, kg/ha	Hydrolyzable nitrogen, mg/kg of soil	
			Control		Response to nitrogen with Irr.			
			Without irrigation	With irrigation			Spring	Final
Winter wheat	1954	Spring wheat	—	19.7	1.5	17	58	—
Same	1955	Winter wheat	—	17.8	1.2-2.6	17	45	35
Same	1955	Sod	16.2	31.5	None	17	113	52
Spring wheat	1954	Melons	4-6	17-19	1.0-2.1	35	60	35
Potatoes	1954	Winter wheat	86	169	8.0	35	62	30
Corn	1955	Spring wheat	37	78	10-14	70	70	50

N/ha) applied to winter wheat following grain gave yield increases of 1.2-2.6 cntr grain/ha. Yields of spring wheat following melons were increased 1.0-2.1 cntr/ha by applying 35 kg N/ha. Winter wheat following sod had ample nitrogen, and the application of nitrogen fertilizer did not increase its yield.

Phosphate Regime

Calcareous chernozem contains 0.16% P_2O_5 in the plowed layer, 0.13% in the subsoil (average of many determinations on different collective farm fields). Leached chernozem is richer in total phosphorus, containing 0.17-0.18% P_2O_5 in the 0-40 cm layer. In the calcareous chernozem 38-44% of the phosphorous, and in leached 33-35%, is combined with soil organic matter (forms of phosphorous determined by the method of D. M. Kheifets). The organic phosphorous in Ciscaucasian chernozems consists mainly of very stable nucleic acid compounds (78%-80% of the total organic phosphorus).

We determined the content of soluble phosphorous in the investigated soils by acetate buffer extraction as modified by D. M. Kheifets. The content is small and similar for both types of Ciscaucasian chernozem, averaging 20-30 mg P_2O_5 per kg of soil in the plowed layer, 6-16 mg in the subsoil. Substantial changes in the content of soluble phosphorous were not observed during the growth of plants either with or without irrigation.

Yields were different with different moisture on the same soil. For example, in the experiment with spring wheat, 19.4 cntr of grain/ha were produced without fertilizer with a vegetative irrigation of 500 m^3, and 26.7 cntr/ha with a pre-irrigation of 1000 m^3 and later vegetative irrigation of 500 m^3. Thus, at a higher rate of irrigation, wheat used a greater quantity of soluble nutrients, including phosphorous. This is also shown by the yield increases from phosphorous fertilizer in the same experiment. With one vegetative irrigation the increased grain was 4.9 cntr/ha from 10 kg P_2O_5 in rows, and 4.1 cntr/ha from 40 kg/ha broadcast before plowing; with pre- and vegetative-irrigations, the increases were 1.9 and 3.5 cntr/ha, respectively. Thus, with increased moisture, crops use more soluble phosphorous from the soil itself and less fertilizer phosphorous.

A considerable part of the fertilizer phosphorous remained in the soil in a soluble form during the growing season. On plots fertilized with superphosphate, 10-30 mg more soluble P_2O_5/kg of soil was observed in the plowed layer than in non-fertilized soils.

We tried the following soil tests for phosphorous; Truog, Chirikov (0.5 $\underline{N}$ CH_3COOH), and D. M. Kheifets acetate buffer extract. According to the first two methods, the plowed layer Ciscaucasian chernozems contain 160-200 mg P_2O_5/kg of soil, which shows (according to indices established for these methods) an adequate amount of available phosphorous for plants. This does not agree with the results of the field experiments, in which the application of phosphorous fertilizers always gave more or less yield response. The results of the field experiments correspond more closely with data from the acetate buffer extracts (20-30 mg P_2O_5/kg of surface layer soil

But there are no indices in the literature relating the need for phosphate fertilizers to analyses of acetate buffer extracts. These indices are difficult to establish, and must be determined by soil analyses in field experiments with fertilizers.

Potassium Regime

The potassium requirements of crops on irrigated chernozems of the Rostov Oblast' are fully satisfied because of the large amount of soluble potassium in them (Table 8).

Immediately after irrigation the amount of exchangeable potassium increases in the soil, especially in the plowed layer. For example, in Table 9 some data are presented for calcareous chernozems on collective farm fields (Koisug, Bataisk region). As was expected, considering the high content of exchangeable potassium, yields on the irrigated collective farm fields of Bataisk region showed no response to potassium fertilization. The results of this experiment are presented in Table 10.

CONCLUSIONS

1. In the arid climate of Rostov Oblast', irrigation of Ciscaucasian chernozems sharply increases crop yields. From 1953 to 1955 irrigation under field conditions almost doubled the yield of winter wheat and potatoes, and gave a three- or four-fold increase in yield of spring wheat on collective farms of the Bataisk region. Thus, irrigation leads to considerable mobilization of soil nutrients: nitrogen, phosphorous, and potassium.

2. Some deterioration in soil physical properties (compaction of surface layer, decreased water entry, decreased amount of water-stable aggregates) takes place with pre-irrigation of fallowed fields and temporarily slows nitrification.

3. The rate of nitrification in the soil under grain crops depends on the previous crop. It proceeds slowly following grain crops, more rapidly after sod and fallow. Following grain with irrigation, it is necessary to apply small

Table 8

Exchangeable and total potassium contents in chernozems of Rostov Oblast'
(data of D. V. Fedorovski)

Depth, cm	Exchangeable potassium, mg K_2O/kg of soil				Total K, %	
	Calcareous chernozem			Leached chernozem	Calcareous	Leached
	Without irrigation	Irrigated			chernozem	
		15 years	2 years	2 years		
0—20	370	420	450	530	1. 72	1. 80
20—40	315	230	301	308	1. 68	1. 73
40—60	275	200	246	246	1. 52	1. 69

Note: Exchangeable potassium was determined flame photometrically in extracts according to the method of A. L. Maslova (0. 0 N ammonium acetate solution), with a soil to solution ratio of 1:10 and one hour of shaking.

Table 9

Effect of irrigation on exchangeable potassium content
(mg K_2O/kg of soil)

Depth, cm	Winter		Spring		Potatoes		Alfalfa	
	Wheat							
	before	after	before	after	before	after	before	after
	irrigation		irrigation		irrigation		irrigation	
0—10	330	400	451	470	458	473	443	530
10—20	370	382	458	465	438	450	411	423
20—40	275	282	298	288	341	306	280	284
40—60	192	222	231	245	258	269	262	258

Table 10

The effect of potassium fertilizers on the yield of several crops on Ciscaucasian chernozems with irrigation

Crop	No. of experiments	Year of experiments	Yield, cntr/ha		Response to pot. fertilizer, cntr/ha
			P	PK	
Winter wheat	8	1954	25.3	24.1	- 1.2
" "	17	1955	17.9	15.3	- 2.3
" "	18	"	31.6	28.7	- 2.9
" "	19	"	33.7	34.0	+ 0.3
Potatoes	6	1953	107.0	117.0	+10.0
"	15	1954	177.0	184.0	+ 7.0
Alfalfa for hay	4	"	53.8	54.0	+ 0.2
Alfalfa for seed	4		4.9	5.7	+ 0.8

amounts of nitrogen fertilizer before seeding. In most cases the nitrification rate in Ciscaucasian chernozems correlates well with the content of hydrolyzable nitrogen. With 30-60 mg of hydrolyzable nitrogen per kg of soil the Ciscaucasian chernozems respond to nitrogen fertilization, but with higher contents (sod, fallow) nitrogen applications are ineffective.

4. The available phosphorous supply in Ciscaucasian chernozems is deficient without irrigation: 10-30 mg P_2O_5/kg of soil by the acetate buffer extract. The available phosphorous supply does not change with irrigation, but its uptake by plants increases. The effectiveness of phosphorous fertilizers on Ciscaucasian chernozems depends on the rate of irrigation. The higher the rate of irrigation, the more phosphorous is used from the soil. Thus, with increasing irrigation rates, lower amounts of phosphorous fertilizers can

5. The potassium nutrition of plants on Ciscaucasian chernozems is entirely adequate, owing to a large amount of exchangeable potassium in the soil, which increases with irrigation. Potassium fertilizers will not be effective in the near future on these irrigated chernozems.

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SOLODS AND GRAY FOREST SOLODIZED SOILS OF THE NORTH KAZAKHSTAN FOREST STEPPE

A. M. DURASOV, Kazakhstan State University

The forest steppe regions of north Kazakhstan, especially those located in the west Siberian plain, constitute an area where the processes of soil solodization are widely developed. In this respect, this region occupies first place among the other territories of the Soviet Union, along with the remaining part of the forest steppe belt of west Siberia.

Information regarding the solods of west Siberia and north Kazakhstan appeared in the literature a relatively long time ago. The geologists Vysotskiy (5) and Krasnopolskiy (20) (who worked at the end of the last century along the route of the Trans-Siberian railroad then under construction) mentioned, among other soils, the so called "white crests" found in birch breaks. They were evidently referring to solods. Similar information on solods are found in the publications of Vydrin and Rostovskiy (4), Gordyagin (7), Tanfil'ev (23), and in a group of publications by soil scientists of the Pereselenchsk Administration. Several investigators, e. g. , Ya. Gordyagin, although not especially concerned with the genesis of solods, noted their morphological similarity to podzolic soils and at the same time pointed out their differences from the latter.

A much more detailed description of the solods of west Siberia and in part, of north Kazakhstan is given by Gorshenin (8). The author made use of the conclusions of K. K. Gedroits (6) just then published and for the first time discussed at length the genesis of solods in the territory that he described. He relates their formation to the occurrence of woody plants along the depressions.

K. P. Gorshenin devotes special attention to solods and solodized soils in his second publication (9), where he also gives their agricultural characteristics.

Besides Gorshenin, the solods and solodized soils of west Siberia and north Kazakhstan were described in the post-revolutionary period by Berg (2), Gus'kov (10), Ivanova (15-17), Bazilevich (1), Storozhenko (22), Kolesov (19), Tolchel'nikov (24), and many others, including the author of this paper (11-13).

However, it should be noted that along with undoubted progress in studying these soils, some authors underestimated the extent of the solodization processes in west Siberia and north Kazakhstan. Therefore, the soil scientists of the K. A. Timiryazev Agricultural Academy (26) separate in north Kazakhstan leached chernozems, gray forest and even sod-podzolic soils.

In papers (11-14) published earlier we showed the absence of leached chernozems in north Kazakhstan which exhibit a great deal of effervescence and are not leached but solodized, having been formed as a result of the evolution of solonized chernozems. Sodium is present in their adsorption complex and cannot be found in leached chernozems.

Materials are presented in this paper which suggest the absence of gray forest and podzolic soils in the forests of north Kazakhstan, i. e. such soils as could be identified with those of the forest steppe and forest zones of the Russian plain. These materials partially supplement the data presented in a paper recently published by Ivanova (17).

Solods in the forest steppe belt of north Kazakhstan occur in birch forests and birch breaks, which are known to exist in depressions. The most typical solods are found in the forests of the most northerly areas of north Kazakhstan and in the Kustanay Oblast'. In the mountain pine-birch forest steppes of the Kokchetav highland solods occur in portions of birch forest growing between mounds in low areas.

It will be noted that solods are not continuously distributed. To observe a typical solod, a profile must be made in the lowest part of a depression and then only if it is not swampy. The most typical solods occur where there are relatively dense stands of woody plants. Solods found in a dense forest can be completely devoid of grass. The soil is sometimes covered with a litter of partially decayed leaves 1-2 cm thick. A light-gray solodized horizon starts almost directly below this layer. Sometimes, however, solods occurring in forests have grassy forest plants which form a rather compact sod 5-7 cm thick. Here the solodized horizon lies directly below the sod.

We do not consider it necessary to dwell at length on the genesis of solods since this has been sufficiently discussed in the literature. Western Siberia and north Kazakhstan solods are the final stage in the evolution of solonetzes, according to Gedroits (6), and supported by a number of investigations (2, 8, 9, 10, 15).

Developing the theory of Gedroits on the solodization of soils in west Siberia, Basilevich (1) notes that "a solonetzation, whatever its degree, can be divided into at least two parts: 1) steppe formation - when conditions arise where the saline soils are no longer in contact with ground water, 2) solodization - when the water table fluctuates or drops very slowly."

The steppe formation process of soils in the saline series under the conditions found in north Kazakhstan leads to the formation of chernozems or chestnut soils. However, as a result of the solodization of solonetzes, solods are formed, culminating in a series of salinized soils.

The process of leaching solonchaks, which is caused by the slow lowering of the water table and leads first of all to solonetz formation, takes place most intensively later on because of having moved from the north of the forest, localized along moist places, to the depressions and makes possible the accumulation of moisture in these places. We wish to emphasize here, the fact that the existence of solods in birch breaks is one of the most conclusive proofs of the encroachment of the forest onto the steppe; if one considers that the birch breaks represent the remnants of dense forests apparently once abundant here, then podzolic soils should be found. True, there are the attempts of Tsiganov (25) (based on a dogmatic interpretation of Vil'yams [3] views) to explain the genesis of solods as taking place during the change from forest into meadow and subsequent development of the salinization. However, in this event the most typical solods would not be found beneath a dense forest cover, but rather along treeless areas between breaks.

In addition to the solods in the forest steppe belt of north Kazakhstan, both the west Siberian lowland and the Kokchetav highland contain unusual gray forest solodized soils. In the west Siberian lowland they occur in birch breaks with more sparse stands or in forest clearings. Where a birch stand is located in a clearly defined depression, at its very bottom (in the absence of swamping, of course solods can be found, while the gray forest solodized soils occur along the periphery of the solods, forming the slopes of the depression. This distribution of gray forest solodize soils along the relief and their alternation wit solods are due to varying moisture conditions. Conditions are favorable for greater wetting i the deeper portions of the depressions found beneath dense forest cover. The solodization there proceeds more intensively and typical solods are formed.

Along the lower portions of the depressions where the trees are sparser and, consequentl there is less wetting, solodization is less intensive.

Within the limits of the mountain pine-birc forest steppes in the Kokchetav highland, gray forest solodized soils occur in birch forests extending along the lower portion of the slopes of hills and along the depressions between the hills. They can also be found in pine forests where they generally have coarse textured soils.

No one has yet written on the gray solodize soils of north Kazakhstan nor were they mentioned in the recent paper of Tolchel'nikov (24), which discusses the solodization of soils in north Kazakhstan. However, in the paper by Kulakov and others (26), these soils are identified with the gray forest soils of the forest steppes of the Russian plain, with which they have nothing in common with respe to genesis or chemical composition, as we shall see below. K. P. Gorshenin described the soils of west Siberia as gray solodized soils. Since they occur chiefly in north Kazakstan forests, which undoubtedly affect their formation, we feel completely justified in calling them gray forest solodized soils.

Although they possess morphological characteristics similar to those of the gray forest soils of the Russian plain forest steppe gray forest solodized soils of north Kazakhsta differ markedly from them in genesis and che ical composition. Whereas the former are th result of the degradation of leached and podzolized chernozems, gray forest solodized soils of north Kazakstan are the last stage in the solodization of solodized chernozems. This is confirmed by the topography where they occur. In the past, solonetzes predominated in the lower portions of the steppe depressions. Owing to the growth of forest vegetation and increase in moisture, they evolved into solods. However, solonetzic hernozems occurred along the slopes of deressions, changing at first into solodized hernozems and then, under the influence of orest vegetation, into gray forest solodized oils. Solonetzic and solodized chernozems re the precursors of gray forest solodized oils. This is proved by the occasional presnce of tongue-like intrusions in the transition orizons of gray forest solodized soils, which s we know are the most typical indication of hernozems in west Siberia and north Kazakhtan, having been preserved here as a relict. s solodization proceeds, the gray forest olodized soils may be transformed into olods. These solods, which are evidently a esult of their evolution, exhibit a thicker sod, hereas the solods that have no sod horizon re a result of the direct evolution of solonetzes. n the later instance the solods are usually the nost typical, representing the highest stage of olodization.

Most of the gray forest solodized soils are ine clay loams. However, the Naurzum pine orest, Borov forest resort, and pine forest elts of the Trtysh contain gray forest solodized oarse textured soils that are sandy loams and ands. To compare the morphological charcteristics of the solods and gray forest solodzed soils of north Kazakhstan, we present the ollowing description of the profiles:

Profile 149. Solod. Location — 5 km NW f Oktyabr'skiy village, Konyukhovskiy rayon, orth Kazakhstan Oblast'. Topography — deression on a gently undulating plain. A dense irch forest with some aspens. There is little rass, consisting of a variety of forest grasses. ffervescence to a depth of 87 cm.

A_0 0-6 cm Sod. Cinnamon-colored mass of ntertwined grass roots.

A 6-21 cm Light gray, structureless, clay oam. Very rich in silica. Transition into ne next horizon is sharp.

B_1 21-43 cm Cinnamon-brown, compact, utlike, moist fine clay loam with wide diffuse ark tongues and fine streaks of humus. Along ne faces of the structured cleavages is a gray ncrustation of silica. Furthermore, along ne horizon are ochre-yellow spots on sesuioxides. The transition into the next horizon s gradual.

B_2 43-87 cm Somewhat lighter than the roceeding horizon. Very compact, nutlike, ne clay loam with streaks of humus with chre-yellow spots of sesquioxides. The ansition into the next horizon is gradual.

C 87(110) cm Gray, yellow-brown moist lay. Somewhat more friable than the proceedg horizons with ochre-yellow spots of sesuioxides with compact carbonate concretions.

Profile 115. Gray forest solodized fine clay loam. Location -- 7 km WNW of the settlement of Kines, Oktyabr'skiy rayon, north Kazakhstan Oblast'. Topography -- very gentle slope with a slight depression on the plain, which opens to the east into the Ishin valley. Farmland -- a small birch stand with young growth of aspen and dog rose. Woody plants are sparse. Effervescence to a depth of 92 cm.

A_0 0-10 cm Sod. Dark cinnamon, compactness due to numerous grass roots. Faintly granular, fine clay loam. The transition is clear.

A 10-20 cm Cinnamon -- with spots of silica. Coarsely granular, moist, compact fine clay loam. The transition is gradual.

B_1 20-40 cm Cinnamon-brown with gray spots of silica along with dispersed streaks of humus. Coarse granular to nutlike, moist, clay. The transition is gradual.

B_2 40-92 cm Cinnamon-gray-brown, nutty, very moist, very compact, clay. Diffuse dark tongues of humus are still present. The transition is gradual.

C 92(115) cm Yellow-brown blocky clay with spots of carbonates.

The morphological description of coarse-textured solodized soils was given in a recent paper of Ivanova (17). Although the author calls these soils solodized sod or sod solods, they are undoubtedly related to the coarse-textured gray forest solodized soils, having only a less developed humus horizon. For that reason we shall not dwell on the morphological characteristics of the coarse-textured gray forest solodized soils that we have investigated.

We may conclude from a comparison of the morphological descriptions of the solod profiles and gray forest solodized soils that the latter differ from the former mainly in having a less pronounced solodized horizon, which in the case of the solodized soils is not continuous and is coarsely granular in contrast to the solods in which this horizon is structureless.

Turning to the physical and chemical data in the table, we see that typical solods (except, perhaps, the uppermost horizon) contain a small amount of humus, whereas in a solodized horizon there is no humus at all. However, in the lower B_1 horizon it increases somewhat and then decreases again with depth. This unusual distribution of humus along the solod profile is caused by the breakdown of the adsorption complex of the soil connected with the solodization process and the leaching of organic colloids deep into the profile.

The upper horizons of solods are acid, but the horizons become increasingly basic with depth until they are clearly so.

Gray forest solodized soils may contain a substantial amount of humus in the upper horizon, which diminishes very rapidly with depth. In this respect, as with the morphological characteristics, the soils described resemble the gray forest soils of the forest steppes in the Russian plain. The upper horizons, just as in the solods, are weakly acid while the C horizons are alkaline.

Solods with a generally fine texture have a coarser texture in the solodized horizon, in which the clay fraction is decreased. The B horizon, on the other hand, is characterized by a much finer texture than the solodized horizon. This phenomenon, together with the unusual distribution of humus throughout the profile, indicates that small colloidal particles migrate into deeper horizons of the soil, i. e. it confirms the solodization process. The results of particle size analysis of a gray forest solodized soil (Profile 42) likewise testify to the movement of colloidal particles throughout the profile. Colloidal particles also move in the coarse-textured gray forest solodized soil (Profile 2005), but this process in solods is very pronounced.

Analysis of the water extracts of solods and gray forest solodized soils also confirms the solodization process. Table 1 shows that the upper horizons of these soils contain a small amount of readily soluble salts. The total alkalinity is also low. In the deep horizons the amount of soluble salts increases and the total alkalinity rises. When this occurs the solods exhibit more intensive leaching of the soluble salts deep in the profile than do the gray forest solodized soils. Analysis of the water extracts of solods and gray forest solodized soils confirms their relation to soils of the saline series since the deep horizons contain a substantial amount of readily soluble salts.

The adsorption complex of solods and gray forest solodized soils contain adsorbed sodium. The breakdown of the adsorption complex is shown by the marked decrease in adsorption capacity of the solodized horizon, which is especially pronounced in solods. In this horizon of the solods there is a sharp relative increase in adsorbed sodium. However, the absolute amount of adsorbed sodium in the adsorbing complex of solods and gray forest solodized soils is approximately the same.

From the results of determining the total sesquioxides in 10% HCl extract it is evident that in solods and gray forest solodized soils there is a movement of sesquioxides and that they accumulate in the transition horizons.

This process is more striking in the solod The results of the determination of total sesquioxides and other analytical data confirm the process of solodization. They correlate well with the data obtained from particle size analysis. The transition horizons in both soils, where the maximum accumulation of sesquioxides occurs, has a finer texture.

One may conclude from a comparison of th analytical data examined with Ivanova's mate (17) in the pine forests of north Kazakhstan that in the birch and pine forests in the north part of the Republic the solodization process will develop regardless of whether the soils have a finer or coarser texture. In this connection we are right in deciding that there ar no gray forest soils analagous to the gray forest soils of the forest steppes in the Russi plain and the piedmont forest belt of southern Siberia and, even more so, the "sod-podzolic soils" in north Kazakhstan. It can be only noted that solodization in the north Kazakhsta forests develops unevenly, depending on topography, character of the vegetation, stand density of trees, and soil texture. It is evide from our data that this process is sufficiently intense in the birch forests of the western Siberian lowland, which may result in the for mation of typical solods. In pine forests solodization in soils was less pronounced (17

Podzolization can not develop in the forest of north Kazakhstan because of the dryness o the climate, relative sparseness of the tree stand, wide distribution of salt-bearing soil material such as tertiary clays, with quatern deposits being found a short distance below them, and the level of the mineralized ground waters (often relatively close to the soil surface). Under these conditions only solodizati can take place.

Genesis of the gray forest solodized soils of north Kazakhstan, their relation to the soi of the saline series, and the fact that they ar not identified with the gray forest soils of the forest steppe in the Russian plain and the pie mont forest steppe belt of southern Siberia are problems both of practical and of theoret cal significance. While it is true that these soils as well as the solods occur for the mos part in forests, and therefore the question of agriculture use does not often arise, neverth less once the forest is cleared, gray forest solodized soils have agricultural value. The meliorative methods are altogether different from those required for soils of the forest steppe in the Russian plain and the piedmont forest belt of southern Siberia.

According to Gorshenin (9), the applicatio of manure with lime is effective on the gray forest soils of southern Siberia. However, his data indicate that the liming of gray solodized soils is not effective. Some slight

Table 1

Physical and chemical properties of solods and gray forest solodized soils of northern Kazakhstan

Profile No.	Depth, cm	Location	Humus	Carbonates	pH	% of particle diameter, mm		Water Extract, %		Adsorbed cations		Total of sesquioxides from a 10% HCl extract
			%			<0.01	<0.001	Solid Residue	Total Alkalinity	Na as % of capacity	adsorption capacity, meq	
		A. Solods										
3	0–5	Bulayen Forest Farm, north Kazakhstan Oblast'	Sod	No effervescence	6.2	38.9	13.0	Not determined		Not determined		5.14
	10–20		0.77	"	6.5	--	--	0.073	0.012	40.3	13.4	3.20
	22–32		3.60	"	6.5	59.8	42.0	0.138	0.010	7.6	23.6	25.79
	70–80		0.74	"	7.0	58.3	43.8	0.114	0.020	4.3	31.0	16.36
	110–120		0.58	9.0	7.1	54.3	23.7	0.144	0.041	Not determined		10.15
148	0–5	5 km NE of Oktyabr village, north Kazakhstan Oblast'	Sod	No effervescence	6.3	56.0	31.6	Not determined		4.8	48.7	
	10–20		0.59	"	7.0	53.8	19.3	0.066	0.038	41.1	8.6	
	30–40		1.12	"	7.1	78.7	56.6	0.148	0.036	19.9	32.1	
	60–70		1.06	"	7.8	70.7	50.4	0.144	0.021	10.6	24.5	
	100–110		0.49	Not det'd.	--	58.8	39.1	0.094	0.043	None	17.5	
		B. Gray forest solodized soils										
115	0–10	7 km west of Kines Oktyabr north Kazakhstan Oblast'	5.06	No effervescence	5.7	Not determined		0.156	0.037	8.6	26.5	
	10–20		1.69	"	5.7	"	"	--	0.031	14.0	19.2	
	30–40		1.43	"	5.7	"	"	0.110	0.036	12.3	21.4	
	70–80		0.70	"	5.8	"	"	0.195	0.059	Not determined		
	105-115		--	3.2	7.5	"	"	0.248	0.053	"	"	
42	0–10	Bulayev Forest Farm, north Kazakhstan Oblast'	4.52	No effervescence	6.4	46.0	20.6	0.102	0.028	6.9	37.3	2.82
	15–25		3.47	"	7.2	64.8	30.8	0.146	0.052	17.4	22.4	13.79
	40–50		1.44	"	7.2	73.7	40.4	0.204	0.079	10.7	16.8	17.03
	110–120		0.75	12.5	8.0	30.6	9.0	0.213	0.083	--	--	11.03
2005	0–10	Irtysh Sovkhoz, Urlyutyub rayon Pavlodar Oblast'	5.00	No effervescence	6.2	34.2	5.0	Not determined		1.6	19.5	
	11–21		1.62	"	6.6	10.5	1.6	"	"	4.2	10.3	
	35–45			"	7.4	20.8	4.8	"	"	3.7	17.3	
	95–105			3.4	8.2	20.4	1.3	"	"			

effect is obtained by adding gypsum. Deep cultivation without use of the moldboard gives good results. The measures necessary to improve gray forest solodized soils are therefore similar to those recommended for solonetzes and solonetzic soils but quite different from the methods recommended for gray forest soils. Consequently, errors in questions relating to the genesis of gray forest solodized soils in north Kazakhstan may well lead to their being incorrectly utilized for agriculture.

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DISCUSSION

XPERIMENTAL CLASSIFICATIONS OF STEPPE ZONE SOILS N THE USSR[1](Communication II)

. N. IVANOVA and N. N. ROZOV

Meadow-Chernozem Soils

The term "meadow-chernozem" refers to oils which develop under meadow-steppe, grass egetation (with deciduous forests) in steppe deressions and river valleys, on upper floodplain erraces and terraces above the floodplain, and n undrained plains. In the literature they are till called "depression chernozem-like soils" nd "valley chernozems." Soils containing reater surface moisture (and usually higher round-water level) are formed because of the ack of surface runoff and, very frequently, as result of the presence of a catchment area. hese are soils with an alternating (leaching ranspiration seepage), and periodic runoff egime. Under these conditions the soil surace is within the range of film-capillary moisure. In the upper horizons of the soil-forming arent material (at a depth of 3-5 m[2]) ground ater is observed. Sometimes capillary-susended moisture is retained for a long time in e lower part of the soil profile and signs f gleying appear.

The soils described have a humus profile imilar to a steppe chernozem, with a neutral r alkaline or, more rarely, a slightly acid eaction. The humus content and adsorption apacity are generally somewhat higher than steppe chernozems, except that in solodized oils the amount of humus may be somewhat ess. Calcium and magnesium carbonates usual- occur near the surface and sometimes somehat lower down. The salt profile varies.

The classification of meadow-chernozem oils is still poorly developed. Transitions meadow-chernozem soils to chernozems on e one hand and to meadow soils on the other are accepted as subgroup divisions. Moreover, the nature of their moisture is considered, -- the predominance of surface or ground water or the occurrence of increased moisture from slow thawing of frozen ground. In this connection, a series of subgroups is defined: 1) surface-meadow-chernozem soils in depressions containing a limited surface runoff, slightly leached, with ground water or water continuously under suspension at a depth of about 5-6 m and lower; 2) subsoil-meadow-like-chernozems with ground water or continuously suspended water at a depth of 4-6 m, -- settling surfaces of undrained plains or terraces; 3) frozen-meadow-like-chernozems -- overlying continuously (up to July) seasonally frozen ground at a depth of about 180-200 cm; 4) surface-meadow-chernozem soils in depressions with increased surface-water collection -- leached, with ground water or water continuously under suspension at a depth of 3-5 m; 5) subsoil-meadow-chernozem soils on undrained plains or terraces with ground water at a depth of 3-4 m; 6) frozen-meadow-chernozem soils directly overlying permafrost (active layer about 150 cm).

As can be seen from the previous paragraph, classifying a soil in one subgroup or another is determined by the nature of its moisture, with which many other properties of meadow-chernozem soils are associated.

Moreover, these soils are divided according to salt profile. The soil salt profile is determined on the one hand by general bioclimatic conditions and on the other, by the degree of ground-water mineralization. Since ground water occurs at a relatively shallow depth and the flow of film-capillary and capillary water may extend from the ground water to the layer occupied by roots and may take part in soil formation (producing in the soil characteristics determined by the composition of the ground water), we believe that it is possible to accept as typical the division of these soils according to soil profile.

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The depth of ground water is given for the summer eriod.

The following subgroups are distinguishable in the meadow-chernozem soils:

1) Meadow-chernozem, podzolized, have a weak acid reaction in the upper horizons, a quartz admixture in horizon A, and a deeper carbonate occurrence. According to total and particle-size analyses these soils show signs of podzolization (mainly residual). Current podzolization occurs mainly in meadow-chernozem soils.

2) Meadow-chernozem, leached, have a neutral reaction (sometimes weakly acidic), carbonates at greater depth and, according to total and particle-size analyses, show no signs of podzolization.

3) Meadow-chernozem, typical (strictly), characterized by a deposit of carbonates within the humus layer and showing neither an eluvial horizon nor saline-solonetzized-solodized.

4) Meadow-chernozem, carbonate, having increased effervescence in the upper part of the humus horizon or at the surface.

5) Meadow-chernozem, solodized, having a weak alkaline reaction, quartz admixture in the A horizon, and a wide fluctuation in the humus; carbonates usually occur in the humus horizon. Total and particle-size analyses and the adsorbing complex show an eluvial horizon. Solonetz-like features and easily soluble salts may occur. A prismatic or nut-like structure of the lower part of the humus horizon is characteristic of these soils.

6) Meadow-chernozem residual-solonetz-like (solodized), having compact and prismatic structure in the humus horizon. Total and particle-size analyses and the adsorbing complex may show an eluvial horizon within the humus profile. There is no quartz admixture, no solonetz-like features, and no salinization. The reaction is neutral.

7) Meadow-chernozem, solonetz-like, having exchangeable sodium, compaction and prismatic structure in the humus horizon.

8) Meadow-chernozem solonchak-like, typified by the presence of readily soluble salts in a soil profile about 150 cm depth. Solonchak-like features are rarely found in meadow-chernozem soils.

9) Meadow-chernozem-like coarse soils develop on sands on plain-type relief and where there is increased surface and ground water. They are distinguished from (strictly) meadow-chernozem soils by the absence of carbonates. Reaction is neutral.

Meadow-chernozem soils are divided into species according to the degree of expression of the humus and salt profiles and the water regime. The degree of expression of the humus profile is determined by the humus content and by the thickness of the humus horizon -- analagous to chernozems. The degree of expression of the salt profile is closely associated with the expression of imposed processes (podzolization, leaching, solodization, the solonetzization and solonchak features, etc.). The main gradations of the salt profile features are given in the literature.[3]

When moisture is increased, subzonal characteristics become merged. We therefore do not envisage separate classification units for them since we consider that they will be included in the species and to some extent in the genera of meadow-chernozen soils.

The general classification scheme for meadow-chernozem soils is as follows:

Group: Meadow-chernozem	
Subgroup:	Main genera:
1) Surface-meadow-like-chernozem	Podzolized
2) Subsoil-meadow-like-chernozem	"Coarse" (Meadow-chernozem-like sand
3) Frozen-meadow-like-chernozem	Typical
4) Surface-meadow-chernozem	Carbonate
5) Subsoil-meadow-chernozem	Solodized
6) Frozen-meadow-chernozem	Residual-solonetz-like-solodized
	Solonetz-like
	Solonchak-like

Chestnut Soils

Soils of the chestnut group are characteristic of dry, grassy steppes and desert (wormwood-Artemisia) and Festuca sulcata-grass steppes. They develop under sparse vegetation where sod-formation is no more than

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[3] Ivanova, E.N. and A.N. Rozanov, 1939. The classification of salinized soils. Pochvovedeniye No. 7. Ivanova, E.N. 1949. The part played by the Dokuchayev Soil Institute in the work to control drought and in the transformation of nature in the forest-steppe and steppe districts of European Russia. Pochvovedeniye No. 12. Ivanova, E.N. 1951. Pedological research. Trudy Kompleksov Nauchn. Eksp., po Voprosam Polezashchitn. Leso razv. Vol. I, No. 2. Lebedev, Yu.P. 1951. The problem of the classification of salinized soils. Doklady Akademii Nauk SSSR, Vol. 31, No. 5. Lobova, E.V. and A.N. Rozanov. 1951. Systemati list of soils for the district of the Main Turkman Canal. Pochvovedeniye No. 5.

0%-60% under conditions of considerably reater dryness and smaller annual biological roductivity than for chernozems. This gives esults in considerably less depth of soil pro- le, shallower saturation of the soil by precipi- ation (except in particularly wet summers) and ne possibility for "bioclimatic development of olonetz-like features" in the soils, associated ith the biological cycle of mineral compounds nd with solutions assimilation. The latter henomenon appears in many areas, though not niversally, in the chestnut-soil zone.

The study of chestnut soils is closely linked ith the names of L. I. Prasolov, S. S. Neustruev, . A. Zakharov, A. M. Pankov, and B. B. Poly- ov and, more recently by E. N. Ivanova, V. A. ovda, K. P. Gorshenin, I. P. Gerasimov, I. F. adovnikov, V. A. Nosin, N. I. Usov, N. D. espalov, A. A. Erokhina, S. P. Matusevich, . M. Petelina, B. F. Petrov, K. A. Ufimtseva, . A. Nogina, G. N. Sambur, F. Ya. Gavrilyuk nd many others.

Within the Eurasian chestnut soil zone three acies groups of chestnut soil subgroups can be istinguished:

1) Ciscaucasian, 2) Volga-Kazakhstan and) Central Asian.

The Ciscaucasian facies group consists of wo subgroups: 1) dark-chestnut mycelium- arbonate and 2) light-chestnut mycelium- arbonate. These subgroups are transitional o the group of grey-cinnamon-brown soils of ne western Eurasian regions (see Figure 1).

The Volga-Kazakhstan facies group consists f three subgroups: 1) dark-chestnut, 2) hestnut and 3) light-chestnut.

The Central Asian facies group also has nree subgroups: 1) dark-chestnut "leached,") chestnut "leached" and 3) light-chestnut leached."

Recently, genetic associations have been oted between the latter subgroups and the rey-cinnamon-brown soils and the "khe-li-lu- ı" of the eastern Eurasian regions. The term leached" has been introduced as a provisional erm. It denotes the removal of readily soluble alts beyond the limits of the soil profile, and some cases, the relatively low occurrence the carbonate horizon.[4]

The chief genetic distinctions between the nestnut soils of the so-called facies groups re determined by the characteristics of the ater-thermal regime of these soils (in its easonal and cyclical changes) and associated ological processes.

All subgroups of chestnut soils, regardless of differences in salt occurrence, have a clearly differentiated profile. The humus horizon (A) has a blocky structure (or slightly platy); the transitional horizon (B) is more or less compacted -- blocky to prismatic. Below this is the carbonate-illuvial horizon, compact, prismatic to nut-like. It superimposes either horizon B_2 (with tinges of humus) or horizon C_c.

A short description of the subgroups of chestnut soils found in the USSR follows.

Subgroups of the Ciscaucasian Facies Group

Dark-chestnut mycelium-carbonate soils, as a result of comparatively deep leaching of salts (which are hardly involved at all in the biological cycle) and the assimilation of carbonates in the spring, are distinguished by surface effervescence and have in the transitional horizon (AB) precipitates of carbonates in the form of incrustations or efflorescences (pseudomycelium). The carbonate-coated horizon appears at a depth of more than 150 cm and the salt horizon at more than 300 cm. Solonetz-like-solodized features are seldom found and are very poorly developed (prismatic structure). There is an accumulation of humus in the upper layer (3%-4%) and the humus profile is extended. There is strong evidence of organism activity in the profile. The profile has a perforated-caprolitic structure with many mussels and tunnels.

Light-chestnut soils of this facies have a general profile structure resembling dark-chestnut soils, but are distinguished by a somewhat shallower profile, lower humus content and mobility of carbonates, and organism activity is less clearly expressed in them.

Subgroups of the Volga-Kazakhstan Facies Group

The characteristics of the origin of the chestnut soils of the Volga-area and Kazakhstan have been intensively studied. They are associated with comparatively less leaching of readily soluble salts from the soil profile, with sodium possibly involved in the biological cycle. The litter from shrubs has a high ash content and the poor shading of the soil surface contributes to increased evaporation of soil solutions which draw salts to the soil surface (or to the root layer) from the relatively close salt horizons. As a result, there is increased concentration of soil solutions in the upper soil horizons, the biological migration of salts is intensified and the phenomena of salinization-solonetzization-solodization begin to appear in the soil formation. These processes are not well developed since the soil is periodically desalinized, desolonetzized and solodized. Since the

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[4] See N. D. Bespalov. 1951. Soils of the Mongolian eoples' Republic, page 159, etc.

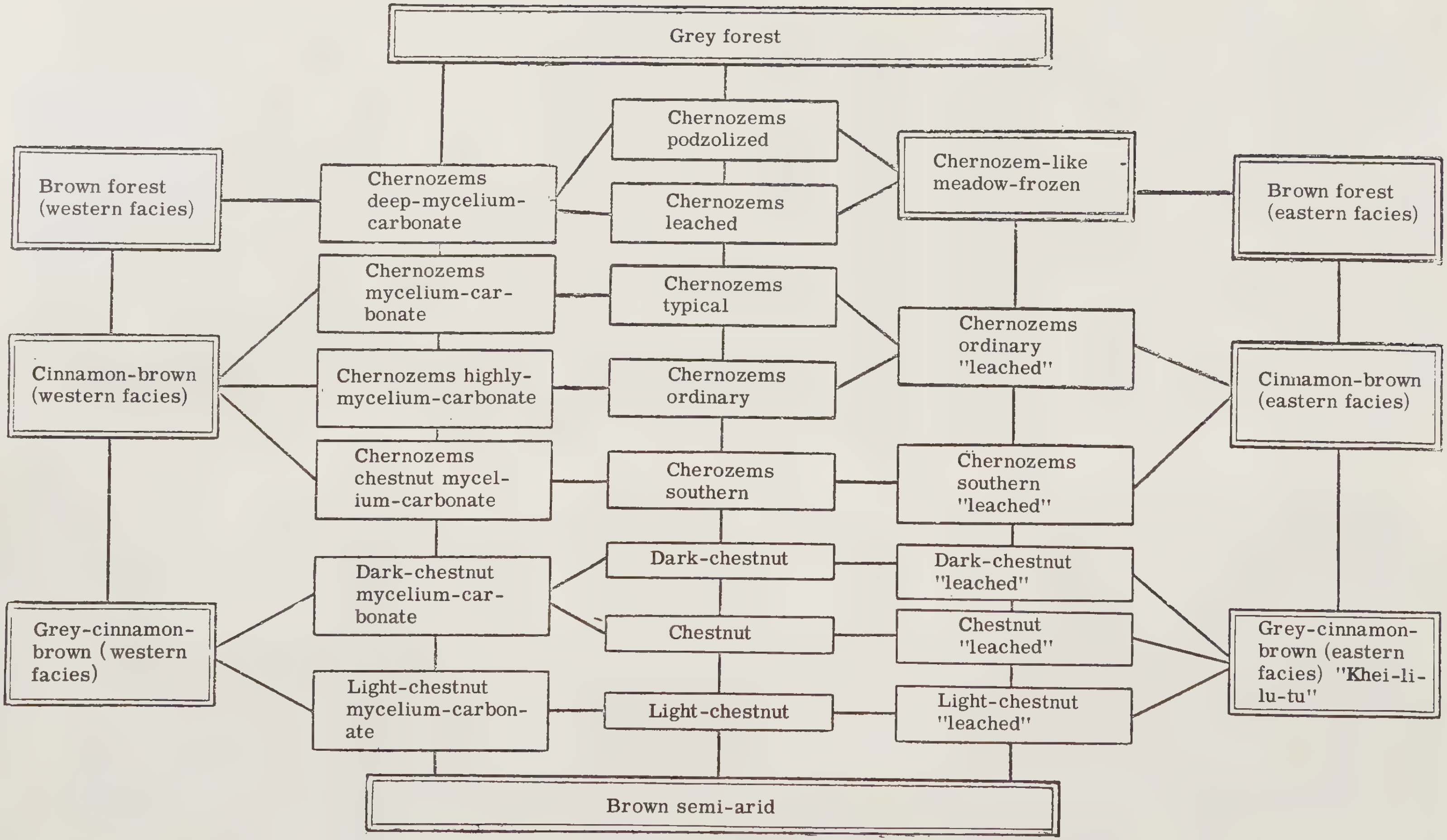
Grey forest
Brown forest (western facies)
Chernozems deep-mycelium-carbonate
Chernozems podzolized
Chernozems leached
Chernozem-like meadow-frozen
Brown forest (eastern facies)
Chernozems mycelium-carbonate
Chernozems typical
Cinnamon-brown (western facies)
Chernozems highly-mycelium-carbonate
Chernozems ordinary
Chernozems ordinary "leached"
Cinnamon-brown (eastern facies)
Chernozems chestnut mycelium-carbonate
Cherozems southern
Chernozems southern "leached"
Dark-chestnut mycelium-carbonate
Dark-chestnut
Dark-chestnut "leached"
Chestnut
Chestnut "leached"
Grey-cinnamon-brown (western facies)
Grey-cinnamon-brown (eastern facies) "Khei-li-lu-tu"
Light-chestnut mycelium-carbonate
Light-chestnut
Light-chestnut "leached"
Brown semi-arid

Fig. 1. - Attempt at a soil classification for the steppe zone, USSR

Geographical relationship of subgroups of chernozem and chestnut soils to other soil groups.
(It is proposed to call chestnut mycelium carbonate chernozems "surface effervescent")

olodization process is only partially reversed eneath shrubs, a few signs of this process ersist after each cycle (salinization-desalinizaon-solonetzization). As a result, a profile s formed (mainly residual) consisting of slighty solonetz-like-solodized soil with poorlyeveloped morphological solonetz-like features he absence of granular structure, some tratification in horizon A and prismatic strucure and compaction in horizon B). In most ases there is no exchangeable sodium. Someimes morphological and chemical signs of olodization are fairly clearly expressed. hese profile features are developed best in the ight-chestnut soils and to a lesser extent in the ark-chestnut soils of the facies under considertion.

Dark-chestnut soils are characterized by the ighest accumulation of humus (3%-5%) for oils of the chestnut group. They possess very oorly developed solonetz-like properties. In he transitional horizon (BC_c) there is a clearly-efined, very compact, "white fleck" subhorizon, hich merges at a depth of about 150-200 cm nto a non-compacted salt (gypsum) horizon.

Chestnut soils are distinguished by a shallow rofile, a smaller humus accumulation, a learer expression of the solonetz-like-solodzed profile, a more pronounced "white fleck" orizon and a salt horizon somewhat closer to he surface (about 130-150 cm).

Light-chestnut soils have the most differeniated profile. Characteristic of them is a lightly solodized, structureless and platy A orizon, a more compact and more clearly-deined B horizon and a very compact carbonate hite fleck horizon, which at a depth of about 30 cm changes abruptly to a porous salt ypsum) horizon. Sodium adsorption is genrally absent from horizon B. Total and partile-size analyses, as well as the exchange apacity, almost always indicate the presence f an eluvial horizon. The absence of worm oles and caprolites, the compact structural rofile, and the presence of krotovina are haracteristics of all soils in this facies.

ubgroups of the Central Asian Facies Group

The origin of the chestnut soils of Central sia has been studied very little. However, in he formation of their profile the heavy late-ummer precipitation which wets the soil to a reat depth and the micro-climatic cycles of ccasional rainy summers are to all appearances f predominant importance. The descriptions f subgroups given below are based on data from he Buryat-Mongolian Republic and the Chita egion.[5]

Dark-chestnut leached soils are characterized by a 3%-4% humus content in horizon A (depth 0-15 cm). Lower down the amount of humus and the root mass decrease abruptly. The structure of horizons A and B is blocky, and there is a slight sod-formation in horizon A. The thickness of A + B is 30-40 cm. A whitish, slightly-compacted horizon of carbonate accumulation in the form of abundant farinaceous precipitates lower down.

A distinctive characteristic of the dark-chestnut leached soils of the Central Asian facies is the absence of readily soluble salts and gypsum throughout the entire soil profile and indications of solonetzization.

Chestnut "leached" soils, in contrast to the dark-chestnut leached soils, contain 2%-3% humus. There are no indications of solonetzization and readily soluble salts and gypsum are leached from the soil profile.

The subgroups of chestnut soils under consideration are divided into genera according to genetic features which depend on the properties of the parent material or on the residual features of the antecedent soil formation.

Because there is less activity of the biological factor than in the chernozems, the generic subdivisions of chestnut soils stand out very clearly and are of great agronomic importance.

In addition to the "strictly chestnut" genus of soils, sometimes referred to as "typical" in the literature, genera defined according to the lithologic features and the texture of the parent material, are distinguished in all subgroups of chestnut soils as follows: residual-carbonate, "coarse" (overlying coarse-textured parent materials) and "loose" (overlying sands).

In the subgroups of the Central Asian facies the following genera are frequently found: deep-effervescing (below the humus horizon) and carbonate-free.

In the subgroups of the chestnut soils of the Volga-Kazakhstan area facies, the following genera are widely distributed: residual-carbonate-solonetz-like, residual-solonetz-like, solonetz-like and solodized -- associated both with the initial salinization of the parent material and, in many places, with the effect of an earlier hydromorphic stage of soil formation. In subgroups of other facies groups of chestnut soils these genera are rare, and they are not found in eastern Eurasia at all. In practice, the term, "residual," is not usually employed in the nomenclature for chestnut solonetz-like soils.

The genera of strictly, or "typical," chestnut soils are the main genera and correspond to the characteristics of the subgroups according to their properties. The genera of residual-carbonate, residual-solonetz-like, deep-effervescing and carbonate-free chestnut soils have, broadly speaking, the same characteristic genetic features as were indicated for the corresponding chernozem varieties.[6] Solonetz-like chestnut soils are distinguished by a significant sodium adsorption and by the present-day manifestation of the solonetzization process under steppe conditions, in the absence of the effect of ground water.

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[5] Data from N.A. Nogina and K.A. Ufimtseva.

"Coarse" chestnut soils are formed on coarse-textured parent materials (sandy loams), the effervescence is at greater depth, and there is often considerable compaction and clay accumulation in B_1 horizon, where prismatic structure is observed. The reaction is neutral. There is no exchangeable sodium. "Friable" chestnut soils are formed on the level surfaces of sands beginning to be overgrown. They are distinguished from sandy loams by friable profile structure and by the absence of effervescence and of carbonate precipitates. The reaction is neutral or slightly alkaline.

Genera of chestnut soils are divided into species according to the degree of development of the humus and salt profiles.

According to the degree of expression of the humus profile, chestnut soils are classified in relation to the thickness of the humus horizon and humus accumulation. At the present time the following classification by humus content in the 0-10 cm layer is accepted for clay loam chestnut soils: dark (rich in humus) 3. 5-4. 5 (5%); medium (normal humus content) 3, 0-3, 5: light (low in humus) 2. 0-3. 0%. These subdivisions within the genera of "typical, " clay loam chestnut soils serve as criteria to distinguish subgroups; for other genera they have a species significance.

The subdivision of chestnut soils by the thickness of the humus horizon has not been worked out yet, although they would be very important in characterizing the various provincial groups of these soils. These subdivisions should conform to gradations of the chernozem subdivisions. As a preliminary suggestion we suggest the following system: medium-thick -- more than 40 cm; thin, 25-40 cm; thin and shallow -- less than 25 cm.

In distinguishing the genera of chestnut soils the quantitative characteristics of their salt profile, expressed by gradations of solonetz-like features, by degrees of solodization and by the depth at which readily soluble salts appear in the soil profile, are of great importance. The main gradations of these features of the salt profile are worked out in the literature (page 50, footnote 3).

Meadow-Chestnut Soils

Meadow-chestnut soils develop on an arid steppe among soils of the chestnut group on the upper floodplain terraces and in relief depressions (hollows, steppe depressions and valleys) with meadow-steppe grass vegetation and shrubs where there is increased surface moisture (nearly always accompanied by a high water table, at 3-6 m) or where there is permanently suspended capillary moisture in the lower part of the soil profile.

The soil surface, under these conditions, has film-capillary moisture and is therefore linked to the ground water, soils of a variable (leachidig transpiration-seepage) and periodic leaching regime. The increased surface moisture in these soils is due to catchment area (pot holes — in the hollows). The soils occur in homogeneous massifs (terraces, hollows, small depressions) or in complexes with solonetzes (soils of shallow depressions). The profile of the meadow-chestnut soils is similar to that of steppe soils. There is a friable-blocky humus horizon, thicker and darker than in soils of the chestnut group. The lower part of the humus horizon (B_1) is compacted, prismatic or prismatic to blocky. Lower down there is an illuvial-carbonate (B_{2c}) conspicuous horizon tinged with humus, of compact structure, prismatic-nut, gradually merging into the parent material (C) which has a compact structure, dense-prismatic, with evidence of gleying (C_g), containing ground water.

The salt profile of the soils is very diverse -- ranging from non-salinized with comparatively slightly mineralized water to solonchak-solonetz-like and solodized with highly mineralized water. The humus content reaches 5%-6%, in the solonetz-like or in the solodized soils, considerably less. The reaction is alkaline or neutral. The soils are saturated with Ca and Mg, with a relatively higher Mg content. In the solonetz-like soils there is adsorbed Na. In salinized and solonetz-like soils readily soluble salts occur above 150 cm.

For division into subgroups, as in meadow-chernozem soils, we propose to proceed according to the transition from chestnut to meadow soils and according to the nature of the prevalent moisture. The following subgroups of meadow-chestnut soils are defined:

1) Surface-meadow-like-chestnut soils having few meadow-like features with deep ground water (5-6 m) in flat depressions with a somewhat lower catchment area;

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[6] See Communication I. Pochvovedeniye, 1958, No. 12.

Table 1

Chestnut Soils

Facies groups of subgroups	Subgroups	Main genera
Ciscaucasian	Dark-chestnut mycelium-carbonate Light-chestnut mycelium-carbonate	Typical Residual-carbonate Residual-solonetz-like
Volga-Kazakhstan	Dark-chestnut Chestnut Light-chestnut	Typical Residual-carbonate Residual-carbonate-solonetz-like Residual-solonetz-like Residual-solonetz-like-solodized Deeply-carbonate? "Coarse" "Friable"
Central Asian	Dark-chestnut "leached" Chestnut "leached" Light-chestnut "leached"	Typical Residual-solonetz-like? Residual-solonetz-like Deeply-carbonate Carbonate-free "Coarse" "Friable"

2) Subsoil -- meadow-like-chestnut soils lso having few meadow-like features with relaively deeply occurring (4-6 m) ground water in teppe-farm plains (terraces);

3) Surface-meadow-chestnut soils in deep ollows with increased surface catchment areas neadow-like), with ground water at a depth of -5 m;

4) Subsoil -- meadow-chestnut soils on teppe-formation plains with ground water at depth of 3-4 m.

The genera of meadow-chestnut soils, as in e case of meadow-chernozems, are distinuished by the nature and properties of the alt profile, associated with the composition of e parent materials and the ground water. The asic generic features of the soils are in the ame sequence as those of the meadow-chernoem soils.

Meadow-chestnut soils are divided into pecies according to the dgreee of humus and alt profile development and according to the ater regime. The degree of humus profile evelopment is expressed by the thickness of e humus horizon and by the humus content. oils are divided into light (up to 3%-4%) and rk (up to 5%-6%) according to their humus ontent. Gradations according to thickness of umus horizon have not been worked out yet. epending on the expression of the salt profile the soils are divided into degrees of leaching of salts and carbonates, solonetzization, solodization, development of solonchak-like features, and gleying. The soils are assigned to species on the basis of texture and to class on the basis of origin of parent materials.

The overall classification scheme for meadow-chestnut soils is as follows:

Group: Meadow-chestnut

Subgroup:

1) Surface-meadow-like-chestnut
2) Subsoil-meadow-like-chestnut
3) Surface-meadow-chestnut
4) Subsoil-meadow-chestnut

Main genera

Leached
Typical (strictly)
Carbonate
Solodized
Solonetz-like
Solonchak-like

Meadow Soils of the Steppes

Meadow soils of the steppes occur among the steppe soils in depressions on undrained plains and river terraces, in deep hollows and steppe lakes where the ground water is close to the surface (1-3 m), under meadow vegetation (sedges, various grasses, meadow grasses).

The soils have a high content of surface -- and subsoil-moisture. Seasonally abundant water and leaching by ground water, and seasonal prevalence of rising water flow making possible a process of secondary salinization, are characteristic of all meadow soils. These are the soils of a variable leaching-seepage moisture regime.

According to the depth of the water-table and its regime we can distinguish between soils having continuous moisture derived from capillary water and soils having periodic capillary moisture (springtime) and periodic film-capillary moisture (autumn). Ground water is mineralized in varying degrees. The degree of mineralization of the ground water is determined by runoff and general climatic conditions. The soils are divided into generally accepted gradations according to the degree of water salinization.

The soils occur in unbroken massifs (steppe lakes) or in a complex with meadow solonetzes (soils in shallow hollows). Instability of the water regime and variability of salt profile over small distances, which produce a very varied profile structure in the meadow soils of the steppe zones, are characteristic of the meadow areas.

The profile of meadow soils has the following structure: at the top is the humus horizon (A); under it is the transitional horizon (B) and parent material (C). Signs of gleying appear immediately under horizon A; these increase with depth and gleyed parent material gradually merges into the water-bearing horizon. In these soils the effervescence line is high for the most part -- in the upper part of the transitional horizon (B) or in the humus horizon (A). Carbonates saturate the soil continuously, making them mottled or, more rarely, whitish. Carbonate precipitates are found also in the humus horizon B, often in the form of veins. Salt efflorescences are observed in the meadow solonchak-like soils.

Meadow soils of the steppes are divided into subgroups on the basis of their transition into meadow-steppe and meadow-bog soils. Meadow soils contain more moisture and, therefore, are not subdivided into subgroups according to moisture character.

Evidently it is possible to consider zonal distinctions of meadow soils, the chernozem-meadow and the chestnut-meadow soils. We are not examining the meadow soils of arid regions here. There are still too few data at present to make a diagnosis of zonal soil subgroups, and we are conditionally classifying them according to the soils' situation in the defined zone. The humus content, thickness of the humus horizon, the group composition of the humus and salt profile characteristics can be used to distinguish them.

The following subgroup of meadow soils of the steppe are noted (the nomenclature of subgroups is still not finally established and is provisional):

1) Chernozem-meadow "variable moisture," "deeply-gleyed," with periodic capillary moisture, 2) Chestnut-meadow "variable moisture, ' deeply-gleyed," with periodic capillary moisture, 3) Chernozem-meadow "constant moisture," "highly gleyed" with constant capillary moisture and 4) Chestnut-meadow "constant moisture," "highly-gleyed" with constant capillary moisture.

Meadow soils of the steppe zone may be divided into genera according to salt profile. The following genera can be distinguished in meadow soil subgroups.

Deeply leached, leached and typical meadow soils are formed above fresh ground water where there is abundant surface flooding and soil-enrichment by a large amount of fresh water.

Carbonate and marly meadow soils are formed in hard ground water, where the latter emerges with a considerable "lateral"-movement of carbonates.

Meadow solonetz-like, solonchak-like and solonchak soils are formed above mineralized water. The degree of soil salinization depends on various combinations of ground-water mineralization, the depth of its occurrence, the value and duration of surface water and the nature of the vegetation, which here shows certain signs of suppression (suppressed Agropyron or mulberry, and with admixture of saltworts and sometimes an overgrowth of marine Artemisia, etc.).

Meadow solodized soils are most often formed above slightly mineralized bicarbonate (sodium) water, the periodic effect which produces alternating processes of salinization-desalinization-solonetzization-solodization in these soils. As a result, very insignificant signs of solodization appear in the soils. These features are intensified with frequent occurrenc accumulate, and gradually assume a clearer shape in the form of separate horizons. Depending on the characteristics of the water regime and the effect of vegetation, the soil may, in its further development, change into a solodi or may remain for a long time in the meadow solodized stage.

Meadow solodized soils may be formed also from meadow solonetz-like soils (and solonetze where there are wide fluctuations in the water supply which lead to the alternation of long periods of salinization and periods of desaliniza tion and solodization.

We are not going into the features of the profile structure of each of the genera distinguished since their properties are, generally speaking, the same as those of the corresponding genera of the soils examined previously. Marly soils are to some extent exceptions in which surface effervescing and the deposition of large accumulations of carbonates (more than 20% CO_2) in the humus horizon, and particularly in the horizon below it, are observed. This content decreases with depth.

Meadow soils are divided into species according to the degree of humus and salt profiles and the nature of the moisture. The degree of humus profile development is determined by the thickness of the humus horizon and the humus content. The gradations of these divisions are still not established. The degree of salt profile development is determined by the degrees of leaching, carbonate accumulation, salinization, solonetzization and solodization of the soils, as well as by the depth and degree of mineralization of the ground water.

The general classification scheme for meadow soils of the steppes is as follows:

Group: Steppe meadow soils	
Subgroups:	Main species
1) Chernozem-meadow with variable moisture, deeply-gleyed 2) Chestnut-meadow with variable moisture, highly-gleyed 3) Chernozem-meadow with constant moisture, highly-gleyed 4) Chestnut-meadow with constant moisture, highly-gleyed	Deeply leached and washed Leached "Typical" Carbonate Marly Solodized Solonchak-like Solonchak

Meadow-Bog Soils

Meadow-bog (lake-bog) soils occupy depressions in the relief containing meadow-bog vegetation (sedges, rushes, reeds (Phragmites communis, etc.). They occur in the steppe zone mainly in depressions in flat plains and along river terraces, in small areas where the ground water is close to the surface (about 1 m). The soils have long periods of surface and ground water with an almost continuous capillary fringe at the surface (with a very short period of aerobiosis not occurring each year). The water regime is stagnant, periodic seepage. The organo-genetic horizon of the soils is differentiated. The upper part of it has formed peat (humic-peat or humic horizon A_0); the lower part represents the humus horizon. The mutual relation of these horizons varies in thickness with different soils. The humus horizon, usually of considerable thickness, has a blocky or friable granular structure (sometimes resembling caviar). It changes into the gleyed horizon B and, below, into gleyed parent material, which passes into the water-bearing horizon.

At present it is possible to distinguish two subgroups in the meadow-bog soil group, according to the degree of surface moisture: meadow-bog humus (relatively low stagnation) and meadow-bog clays (with permanent surface moisture).

Meadow-bog humus soils develop under meadow-bog vegetation consisting of various grasses and are characterized by the formation of humus horizons. Meadow-bog clay soils develop under hydrophytes (reeds), are characterized by poor development of the humic horizon, have a poorly-developed humus horizon and are distinguished by a large accumulation of clay associated with a full surface catchment area.

These are divided into genera according to their salt profile, which is determined by ground-water mineralization and by the amount of seepage.

The following genera can be distinguished: The meadow bog genus corresponds to the general characteristics of the group.

Meadow-bog carbonate soils with effervescence at the surface or in horizon A_1.

Meadow-bog marly soils have greater carbonate accumulations in the humus (A) or transitional (B_1) horizons.

Meadow-bog solodized and solonetz-like soils are compacted and have a prismatic structure in the lower part of the humus horizon (horizon B_1); in the humus horizons A and B_1 of the solodized soils there is a siliceous admixture and whitish mottling; in the solonetz-like soils, horizon B_1 contains exchangeable Na.

Meadow-bog solonchak-like soils contain salt efflorescences.

The general classification scheme for meadow-bog soils is:

Group: Meadow-bog soils

Subgroups:	Main genera
1) Meadow-bog humus (relatively non-stagnant) 2) Meadow-bog clay (with permanent surface water)	Typical Carbonate Marly Solodized Solonetz-like Solonchak-like

Meadow-bog soils are divided into species according to the accumulation of organic matter and the expression of salt profile. Practical gradations have not been worked out yet. The nature of the organo-genetic horizon is determined by the relation of the humic and humus horizons and by the humus content. The degree of expression of the salt profile is determined by the depth of occurrence of the salinized horizon, the salt content, the presence of solonetz-like features, solodization, carbonate content, etc. The same quantitative gradations may be accepted as were indicated above.

METHODS

METHOD OF STUDYING THE BIOLOGICAL CYCLE OF ELEMENTS IN FOREST

N. P. REMEZOV, Faculty of Soil Science, Moscow University (Reply to M. A. Vinokurov and A. N. Tyurmenko)[1]

The biological cycle of elements under the forest canopy is a complex, many-sided process. To encompass all its aspects in a single study is doubtless tempting, but very difficult to accomplish. The investigation should be developed in successive stages.

In a series of investigations on the biological cycle of elements undertaken by the Faculty of Soil Science at Moscow University, the first stage was the examination of the annual cycles in the overall cycle (1944-1951). The task at this stage was to determine by direct chemical analysis of plants the amount of principal nutrients which the forest, as a result of the annual cycle, extracts from the soil, retains in the developing stand, and returns to the soil as litter and dead wood. The establishment of experiments in plantations of various age classes made it possible to determine the characteristics of the long-term cycles.

A general summary of results of this first stage of investigation was given in a paper at the All-Union Conference of Soil Scientists in January-February 1956 (12) and at the Sixth International Congress of Soil Science Society in Paris in the same year (32).

A. F. Tyulin (17, 18, 19) made a counter-proposal to the method used by our Faculty in the first stage of our investigations of the biological cycle. His method was based on soil analyses which indicated that in forest soils of Tellermanov area, the total nitrogen content fluctuated considerably throughout the growing season. Tyulin attributed these fluctuations to nitrogen consumption by the root systems of the oak forest which resulted in decreased amounts of nitrogen in the soil, and to secretion of nitrogen from the roots which increased the nitrogen content in the soil. On the basis of these indirect data, Tyulin concluded that the consumption of nutrients by an oak forest must be approximately ten times as great as that established by direct plant analysis reported by our Faculty.

The inaccuracy of Tyulin's approach to the determination of nutrient consumption of a forest was so obvious that it seemed unnecessary to explain it in print. However, in 1958 Vinokurov and Tyurmenko (5) published a paper recommending Tyulin's approach unreservedly. Therefore, it became necessary to explain the inaccuracy of his method of studying the biological cycle.

The change in total nitrogen content of soil beneath a forest during the growing season was known from Tyulin's work and there was no reason to doubt it. Long-term data on the dynamics of the total nitrogen content of forest soils were published by Feher in 1929-1936 (26, 27, 28). Our Faculty obtained similar results, except that they indicated more precisely (Table 1) that the considerable amount of fluctuation in nitrogen content is observed in the richer soils and that in poorer soils, the nitrogen content remains fairly constant.

Before Tyulin's work, none of those who observed the changes in total nitrogen content of forest soils attributed them, either wholly or mainly, to uptake and secretion of nitrogen by the tree root systems. If we represent the soil as a sterile medium devoid of microorganisms and soil-litter fauna, then changes in total nitrogen content of this hypothetical soil could be attributed only to the action of root systems. However, such an assumption is not applicable to the actual soil, which is the habitat not only for root systems of the higher plants but also for algae, fungi, actinomycetes, bacteria and a varied fauna.

Oligonitrophylous organisms in great quanti-

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[1] Vinokurov, M.A. and A.N. Tyurmenko. 1958. Data on the biological cycle of nitrogen and phosphorus in forest. Pochvovedeniye No. 7.

Table 1

Dynamics of total nitrogen content (%) in soils of oak stand on the Voronezh State Forest, 1953
(Research by E. M. Shmurova)

Soil	Months						
	April	May	June	July	Aug.	Sept.	Oct.
Dark gray-brown forest, sandy loam	0. 26	0. 34	0. 23	0. 22	0. 29	0. 29	0. 29
Gray-brown forest, loam	0. 22	0. 26	0. 23	0. 22	0. 24	0. 23	0. 23
Brown forest sand	0. 15	0. 18	0. 13	0. 14	0. 14	0. 14	0. 13
Light-brown forest sand	0. 11	0. 11	0. 09	0. 11	0. 11	0. 11	0. 11

ties enrich forest soils with fixed nitrogen. A similar influence is exerted by nodule bacteria on the roots of astragalus, vetchling (lathyrus), vetch (vica) and other forest leguminous plants. In deciduous forest soils possessing a nitrifying capacity, the activity of those denitrifyers which reduce nitrates to elementary nitrogen contributes to nitrogen loss. The possibility of partial losses of ammonia formed during ammonification and denitrification is not excluded. The intake by soil of nitrogen and other elements during the process of decomposition of dead vegetation must be considered.

A substantial effect on the chemical composition of the humus-accumulating layer and on its nitrogen and phosphorus content is produced by soil-litter fauna. They intermix this layer with the forest litter, and with the underlying horizons, thereby enriching it in nitrogen and phosphorus, thus decreasing the latter's nitrogen, phosphorus, sulphur, calcium, etc. content. In addition, the fauna introduce nitrogen and other elements into the soil with their excreta and, at the end of their life-cycle, with their dead bodies. The life-span of some is very short.

The activity of both microorganisms and soil-litter fauna has its own seasonal character, so that they may cause regular seasonal changes in soil properties. Feher (27) showed, with a wealth of data, the decrease in numbers and activity of the microflora during the summer drying of forest soils. This was observed in our investigations, too. Zrazhevskii (8) describes the decrease in activity of earthworms and certain other soil fauna during a period of sharp decrease in soil moisture. He also shows that excessive moisture, which impedes soil aeration, has an adverse effect on soil fauna.

The effect of atmospheric precipitation, which controls the movement of soluble compounds of nitrogen and other elements from the forest litter to the humus-accumulation horizon -- and when the fall is greater it is deeper -- should be taken into account. In the ensuing drying period, the soluble compounds rise from deeper layers.

To disregard the effect of microorganism activity and soil fauna on the dynamics of nutrients in forest soils is without doubt a major fundamental error. Variations in the total nutrient content of forest soils depend on many factors, which effects have not been studied from the quantitative viewpoint. It is inadmissible arbitrarily to ascribe all changes, wholly or mainly, to the activity of the roots alone, in the total absence of direct data as to the amount of nitrogen and other elements secreted by the roots of trees.

To demonstrate that all fluctuations in nitrogen content of the soil depend solely on root activity, the following single experiment was presented (19, p. 277). An area of 4 m^2 was completely cleared of forest litter, then the soil was removed to a depth of 20 cm. All visible roots were carefully extracted from the soil. Next, the soil was placed in another previously-prepared hollow, having corresponding dimensions. After this treatment the total nitrogen content of the soil remained almost constant (0. 05%-0. 55%).

Results of the experiment cannot be accepted as convincing. The upper part of the humus-accumulation layer of dark-gray forest clay loams, to a depth of 20 cm, are very highly interwoven with roots of trees, shrubs, and coarse woodland grasses. The removal of the entire root mass from almost a cubic meter (0. 8) of earth involves long and laborious work which inevitably has an effect on the soil fauna. During the sifting of a soil mass of this kind every creature that can jump, crawl or fly left it. Moreover, the removal of roots disturbed the activity of rhizospheric microorganisms, especially bacteria, which utilize the organic compounds secreted from roots as a source of energy. The soil obtained was devoid of roots and improverished to a considerable degree of living organisms.

It is not surprising that a method based on disregard of the part played by the microflora and fauna in forest soils led to a paradoxical representation of the nitrogen cycle. Thus, for a 50-year-old oak plantation a value of 1. 5 metric tons/ha nitrogen consumption by the forest was found, according to the difference between the highest and lowest total nitrogen content of the soil. According to our data, based on analysis of the tree itself, it was only 0. 15 metric tons/ha. On this basis it was concluded that all data for nitrogen consumption by the forest obtained by our Faculty were approximately 10 times too low (17, p. 109). This leads to the following conclusions: a 12-year-old oak stand, according to our data, takes up 29 kg/ha of nitrogen annually from the soil; multiplying this by 10 gives 290 kg/ha, although the nitrogen content of the entire stand is only 172 kg/ha. According to our data, when 20-25 years old the stand absorbs 130 kg/ha; multiplying this value by ten gives 1300 kg/ha, but the total nitrogen content of the stand is 500-550 kg/ha. It follows that the stand annually takes up more nitrogen from the soil than it contains. From the physiological aspect the absorption and secretion of such large amounts of nitrogen through the root system remained unexplained.

In another paper (5) it was stated that a 45- to 55-year-old basswood stand takes 825 kg/ha of nitrogen from the soil. According to our Faculty's data a 40-year-old basswood stand absorbs 73 kg/ha from the soil, and the entire stand, including undergrowth, contains only 703 kg/ha of nitrogen (13).

Supporters of this method of studying the biological cycle are inclined to apply it to other elements as well. In the paper by Vinokurov and Tyurmenko the phosphorus consumption of a 45- to 55-year-old basswood stand is determined in this way as 130 kg/ha P_2O_5, while the content of the entire stand is about 150 kg/ha. The very high P_2O_5 content in leaves (about 2%) and roots (about 0. 5%) of the basswood is surprising. Other authors give considerably lower values.

In the polemic papers under consideration two further objections to the method used by our Faculty were advanced. The first consists of an assertion that the study of the amount of elements taken up by the forest from the soil and partly restored to it later through litter and dead wood represents a revival of the agronomic theory of removal and return (17). The second is that we studied the biological cycle by chemical analysis of felled, not living trees (5, 17).

The consumption by forest of nutrients from the soil and the restoration to the soil of part of them with litter and dead wood represents an objective natural phenomenon existing independently of ourselves. They bear no relation of any kind to the man-made agronomic theory of the artificial restoration to the soil with fertilizers of nutrients removed with crops. With reference to the chemical analysis of felled trees -- to determine the mass of the tree, including its root system, and to perform a total chemical analysis of a living tree is impossible. The total content of nitrogen and ash elements in the leaves, branches, trunk and roots of a tree will not change when it is felled. The critics of my work quote in their papers data of chemical analysis of leaves and roots, not only dead but further treated with hot steam.

The method of studying the biological cycle of elements by means of soil analysis cannot be accepted since it has no theoretical basis and leads to improbable data. There remains the direct plant-analysis method used by our Faculty. This method in principle fully answers the purpose indicated, which does not exclude the possibility of improving it in detail. By this means the annual and long-term minor cycles within the general biological cycle are considered. Further, sub-annual cycles exist whose duration is measured in shorter divisions of time. Another method of approach is necessary to study these. One of the chief characteristics of sub-annual cycles is that the same amount of nutrients can be taken up from the soil by plants and returned to it again many times during a year.

In 1952 our investigations were concerned chiefly with seasonal changes in the chemical composition of the soil and plants. The results appeared in a series of publications (1, 2, 14, 15, 16, 20, 21). In this paper it is necessary to deal in detail with the seasonal changes in the chemical composition of various parts of the tree. To clarify this question, representative trees, two at a time, were taken at the Voronezh National Forest three times in the growing season (spring, summer and autumn) on the same experimental area in a 50-year-old oak plantation. The mass of leaves, branches, trunk and roots was determined and a chemical analysis made of them.

The most substantial variations (Table 2) in the content of the elements studied were found in the leaves and, to a lesser degree, in the branches. From spring to autumn the content of nitrogen, potassium and to a lesser extent, of magnesium in the leaves consistently decreased. The content of silica, calcium and iron, on the other hand, increased towards autumn. These changes were smaller in branches than in leaves. Analysis of the trunk and roots revealed no substantial sub-annual changes in the

Table 2

Content of nitrogen and ash elements in various parts of oak (Site quality III), 1957
(Research by L. G. Bogashova)

Part of tree	Sampling date	Content as % of dry matter (100° C)							
		N	Si	Fe	Ca	Mg	K	P	Total
Leaves	June 10	3,30	0,79	0,01	0,57	0,09	2,34	0,32	7,42
	August 13	2,47	2,23	0,02	1,01	0,08	1,95	0,20	8,96
	Sept. 30	1,97	4,10	0,03	1,17	0,06	1.78	0,32	9,43
Branches	June 30	1,02	0,37	0,01	0,72	0,06	0,96	0,13	3,27
	August 13	0,72	0,40	0,01	1,03	0,05	0,74	0,11	3,06
	Sept. 30	0,70	0,51	0,01	1,05	0,05	0,35	0,07	2,74
Trunk	June 10	0,24	0,05	0,01	0,23	0,04	0,13	0,03	0,73
	July 13	0,24	0,05	0,01	0,21	0,03	0,11	0,02	0,67
	Sept. 30	0,20	0,06	0,02	0,37	0,02	0,11	0,02	0,80
Roots	June 10	0,60	1,06	0,04	0,84	0,08	0,65	0,16	3,43
	July 13	0,62	0,42	0,03	0,98	0,08	0,59	0,10	2,81
	Sept. 30	0,54	1,06	0,03	1,05	0,05	0,48	0,10	3,31

Note: Comma represents decimal point.

content of the majority of elements.

The data obtained show to satisfactory conclusions that the oak's maximum consumption of nitrogen, potassium, magnesium and phosphorus occurred in June. In July there was a considerable decrease in the nitrogen and potassium content. Since the sum of the elements in the leaves increases from June to September, the increase in silica and calcium content was not just relative. The accumulation of these elements in the leaf continues throughout the growing period.

The decrease in nitrogen and potassium content in the leaves and branches was not accompanied by a change in their percentage content in the trunk and roots. The question arises as to the course followed by the nitrogen and potassium lost by the leaves and branches.

According to Raskatov's research (11) carried out in the oak plantations of the Voronezh National Forest, the greatest increment in mass of oaks takes place from June to July; it decreases somewhat in August, mostly (4%-8% of the annual growth) in September. According to our Faculty's data, the annual growth of an oak stand (50 years old, site quality III) contains (in kg/ha): N, 19; Ca, 27; K, 8; Mg, less than 3; sulphur, about 2; remaining elements, <1. The mass of leaves in these oak plantations is 1. 3 metric tons/ha (as dry matter at 100° C), and of branches 0. 86 metric tons/ha. A decrease in the nitrogen content of leaves from 3. 30% to 1. 97% gives a nitrogen loss of 17. 3 kg/ha from the leaves, and a decrease in potassium content from 2. 34% to 1. 78% gives a potassium loss of 7. 3 kg/ha. The total loss from leaves and branches is: nitrogen 17. 6 and potassium 7. 8 kg/ha. These values correspond closely to the amount of these elements used for annual growth. Similar results were obtained for magnesium.

The increase in calcium content in all parts of the tree from May to September, with a considerably simultaneous use for growth (27 kg/ha) confirms its accumulation in the oak stand throughout the growing period. The calculations given convince one that the decrease in nitrogen and potassium content of leaves and branches towards autumn cannot be regarded as evidence of their secretion into the soil in large quantities. This does not exclude secretion in small quantities of some elements by roots into the soil.

In studying root secretion considerable difficulties were encountered. The following temporary method was used: one of the secondary roots of the tree, 30-40 cm long, was dug up, cleaned of soil and subsequently immersed in distilled water. To secure aeration, air was bubbled through for five days. Observations showed that under these conditions the root not only lived but even grew. The interation of roots with water in experiments made in 1956 and 1957 was observed for about a month, after which the water was changed.[2] Experiments were made on roots of oak, pine and spruce. In the first half of the summer no secretions perceptible by analysis were detected; in August secretions of small quantities of K, Ca, Al and P were noted. Potassium secretion amounted to 1 mg/l as K_2O alumina 0.12-0.24 mg/l Al_2O_3.

In order to exclude inequality of ion concentrations in the cell sap and the solution, experiments were conducted substituting nutrient solutions of salts for distilled water. By this means it was possible to obtain clearer results. For instance, it was possible to show that in the first half of the summer an absorption of K_2O of 41 mg/l for pine and 50 mg/l for oak took place from a solution of KNO_3 (200 mg/l), while in August the K_2O content in the pots increased up to 52 mg/l in the experiment with oak and up to 47 mg/l in that with pine. These studies confirmed the presence of root secretion into the soil of some elements in the autumn (Studies by E. M. Boriskina-Samoilova). Unfortunately, with the method employed it was not possible to judge the amount of these exudations for the entire tree.

An hypothesis developed that during prolonged interaction between roots and solution the alternating processes of intake and secretion may compensate for each other. In the summer of 1958, experiments were conducted using the same method with a change of solutions every 12 hours; in the evening (after the day period) and in the morning (after the night period). Twelve hours of interaction between roots and solution was sufficient for the absorption on release into the solution of Ca, Mg and K (Study by N. Titova). Further research in this direction requires improved methods.

Until recently it was widely thought that atmospheric precipitation leaches nitrogen and ash elements only from leaf litter, i.e. from dead leaves. Green leaves hanging on the tree, by the force of turgor, firmly retain these elements. The possibility of leaching of elements from leaves of trees, from bushes and from grass cover was not usually taken into account in explaining the causes leading to change of content of these elements both in leaves and soil. Moreover, the literature contains many indications that atmospheric precipitation leaches many elements from living leaves.

As early as 1804 de Saussure (34) wrote that leaves pass on to rainwater the salts which they contain. In 1883, Councler (24) adduced experimental confirmation of this. He found that the leaves of box elder (Acer negundo) grown under greenhouse conditions, compared to leaves of the same tree grown in the field under the open sky, contained more sulphuric acid (3.90% as against 0.97%), phosphoric acid (2.60% as against 0.46%), potassium (9.67% as against 4.51%) and sodium (0.12% as against 0.09%). He ascribed the lower content of these elements in the leaves of the box elder in the field to leaching by atmospheric precipitation.

Later, Arens (22, 23) wrote of the leaching by rainwater of ash elements from the leaves of trees. According to his observations, a few hours' rainfall may decrease the element content of leaves by 10%-30% and the potassium content by as much as 50%. In one of these investigations, leaves of a beech forest containing 16.2 kg/ha K_2O, lost 9.8 kg/ha after 24 hours of rain. Losses almost as great are observed in five hours of rain.

Arens points out that the ash element content of leaves increases in dry weather and that a fresh rainfall again results in leaching. In the growing season this is repeated frequently and the sum gives a considerable value which describes the intensity of the branch of the biological cycle described.

Arens suggested calling this phenomenon "kuticuläre Exkretion" to differentiate it from leaching of dead leaves.

In this connection the investigations of Lausberg (30) are interesting. From an isolated horse-chestnut tree, he picked off leaves daily at the same hour and analyzed them. The data obtained show a decrease in calcium and potassium content after each rainfall, and a return to the previous level after ensuing dry weather.

Not only rain but also humid mist produced a decrease in the content of these elements.

Tamm (33) carried out more prolonged investigations in 1950 in the environs of Stockholm (Table 3).

Table 3

Leaching of ash elements by rainwater
from the crowns of trees
(Research by C. O. Tamm)

Site of rainwater collection	Entered the soil from Oct. 19 to Nov. 30 (kg/ha)		
	Ca	K	Na
Open field	0.4	0.3	0.6
Forest clearing	0.5	0.3	0.5
Under spruce	>2.2	>2.4	>3.7
Under pine	2.5	2.7	3.2

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[2] The method was described in greater detail in Bogashova's paper (1).

Under spruce the calculation was incomplete, as the funnels used (24 cm in diameter) gave more water than the flasks could hold. The data analyzed (Table 3) show that rainwater leaches a considerable amount of bases from the crowns. Tamm writes that only one-fifth of the total annual precipitation fell during the period of his investigation. The actual annual intake by the soil of nutrients leached by rainwater from leaves is considerably higher. Rainwater leaches more ash elements from deciduous than from coniferous species. Examining rainwater on September 26, 1950, Tamm found calcium (per mg/l): in water from pine forest crowns 4. 0; in water from oak plantations 9. 1; in water from birch plantations, 7. 2; the corresponding figures for potassium were 6. 3, 15. 0, 17. 4, etc.

Investigations carried out in New Zealand by Will (35) in a 30-year-old pine forest (Pinus radiata, D. Don) in 1954-55 (Table 4) are another example.

We must pause again for one important conclusion. In recent times the isotope method has been used for quantitative study of root secretions from trees. The appearance in the soil of P^{32} (or another element), however, introduced under the bark of a tree or on the leaf surface cannot serve to determine the amounts of the element exuded by the roots. Its appearance in the soil may be the result of leaching from the leaves; i. e. of the phenomenon of "culticular exudation." This was confirmed experimentally in the work of Mes (31).

The last question to be examined concerns the effect exerted on the biological cycle of elements by the dying off, during the tree's life, of part of the tree roots.

Taking fruit trees as an example, Kolesnikov (9) showed that the production of new, and the dying-off of old, root endings and even of entire "root systems" goes on throughout the entire growing season. Great difficulties of methodology are encountered when determining the extent of the participation of the dying-off of minute roots and absorbing rootlets. For this purpose, Orlov (10) proposed a method based on selecting, from a soil monolith of 1000 ml volume by means of forceps and needle, a root of <0. 3 mm diameter with subsequent additional examination under a magnifying glass. This work is extremely laborious. Using his method, Orlov concluded that the annual value of dying-off amounts to 0. 6 metric tons/ha. Unfortunately the object of his study was atypical — spruce stands on chernozem.

Table 4

Intake by pine-forest soil of ash elements from litter and rainwater,
November 26, 1954 to June 2, 1955
(Research by G. M. Will)

Place of collection	Precipitation (mm)	Litter (g/m²)	Entered the soil (mg/m²)				
			Ca	Mg	K	Na	P
Open area	687	—	1. 3	1. 4	2. 2	23. 4	—
Under pine	420	—	4. 7	12. 6	21. 5	81. 5	4. 9
Pine litter-fall	—	252	61. 6	21. 2	16. 5	10. 4	24. 6

In the moister climate total rainwater leached more potassium from forest crowns than was contained in litter. One cannot agree with Will's proposal to calculate the nutrient intake by the soil from the sum of its content in litter and rainwater. The elements leached from the crowns by rain are absorbed again from the soil by the root systems of trees when dry weather returns. The intake of elements by the soil with rainwater is related to the subannual cycle which is incorrect to include on an equal basis with the litter in the annual cycle.

The sum of elements leached from forest crowns in a year serves as an index for the amount of elements passing through a plant, but not for the requirement of elements for the growth of that plant.

Preliminary experiments carried out in 1958 at the Voronezh National Forest confirmed the considerable extent of leaching of nitrogen, potassium, calcium and phosphorus from leaves in oak and aspen stands (research by I. K. Sviridova).

In 1956, using Orlov's method, a study of the root systems of a 50-year-old oak stand (site quality III) in the Voronezh National Forest was undertaken. The soil samples for this study were taken three times during the season -- in June, July and August, between the 14th and 21st of each month. For the first two months the total mass of living roots of a diameter <0. 3 mm in the 0-10 layer[3] amounted to 0.8 metric tons/ha; in August it decreased to 0.5 metric tons/ha, which indicates a prevalence of dying-off of roots. If one agrees with Orlov's judgement (10), that half of the roots die off, then the proportion which dies off will amount to 0.4 metric tons/ha, which approximates the decrease of living roots for July to August.

Chemical analysis showed (Table 5) that the percentage of silica, iron, aluminum and potassium in roots increased with a decrease in diameter. There were no regular changes in calcium and magnesium content. The nitrogen content was not determined for technical reasons.

Table 5

Results of the chemical analysis of oak roots of various diameters
(Research by E. M. Boriskina-Smoĭlova)

Root diameter	Content as % of dry matter (100° C)						
	Si	Fe	Al	Ca	Mg	K	P
>7 cm	0.07	0.01	0.14	0.94	0.27	0.40	0.08
7-0.1 cm	0.19	0.04	0.24	1.36	0.30	0.71	0.08
1-0.3 mm	0.52	0.15	0.34	0.56	0.22	0.72	0.08
<0.3 mm	1.06	1.00	0.83	0.71	0.22	4.16	0.14

Table 6

Comparison of ash element content in roots having a diameter < 0.3 mm and in litter (kg/ha)

Content	Si	Fe	Al	Ca	Mg	K	P
In absorbing roots	7.7	7.2	6.0	5.1	1.6	8.3	1.0
In litter	17.9	0.6	2.1	66.0	10.7	15.8	5.6

Comparison of the ash element content of his part of the roots with litter per acre (Table 6) shows that considerably more aluminum and iron is retained in the minute roots than in the annual litter on the ground. The considerable silica and potassium content in the roots, amounting to about half the annual intake of these elements with litter, should also be noted. The phosphorus content is relatively small.

Thus, the dying off of roots <0.3 mm in diameter has a substantial effect on the biological cycle of elements. This effect is particularly clearly shown in the aluminum and iron cycle. Investigations on this aspect continue.

The biological cycle of elements in a forest is a complicated polycyclic process depending on the combination of many factors. A leading part is played by the activity of forest vegetation in conjunction with the soil fauna.

This activity takes place under changing conditions of climate and weather.

Long-term cycles are composed of successive annual cycles. The content of annual cycles varies according to the period of development of the stand (age classes), depending on the increase of nutrient and moisture requirements of forest-forming trees with age, the gradual natural thinning of the stand, variation of light, development of underbrush, soil cover, etc.

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[3] A large proportion of roots of this diameter is ontained in the top 5 cm; 1/10 is contained in the -10 cm layer and below 20 cm, there are almost one. Lateral roots leading off the large roots head pwards for the humus horizon where they branch ff extensively.

The annual minor cycles within the general biological cycle of elements are conditioned by the removal of a specific amount of elements from the soil during growth and by the return to the soil, in the same year, of part of them with litter and dead wood. Here the annual water cycle should also be taken into account.

The work of the Soil Science Faculty of Moscow University was directed primarily towards the study of long-term and annual cycles within the biological cycle of elements. For this purpose a corresponding method of study was evolved which vindicated itself in practice. The lack of agreement in the carbon and oxygen cycle is to be attributed to a defect in the method caused by difficulties in analytical procedure.

The study of sub-annual cycles within the biological cycle is the most complex. Their duration may vary widely; some of the processes vary hour by hour. The sub-annual cycles consist of the appearance and dying-off of bacteria, algae, fungi and a number of microscopic and larger soil fauna, the formation and dying off of root hairs, the synthesis and decomposition of organic matter, the leaching of elements from leaves by rain, dew and mist and their re-absorption by roots, ion exchange processes between plant roots and the soil, and nitrogen fixation and denitrification. Leaching by atmospheric precipitation and capillary rise, etc. have a substantial effect. It is impossible to list all these individual minor cycles. At the second stage of our investigations we began the study of a number of sub-annual cycles. Some of the results obtained are given by way of example.

The method recommended by Vinokurov and others of studying the biological cycle of elements by means of total soil analysis cannot give even an approximate idea of a single minor cycle within the general biological cycle and should, therefore, not be adopted.

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EXPERIMENTAL CLASSIFICATIONS OF THE WATER-RETAINING CAPACITY OF FINE SAND AND COARSE SILT FRACTIONS[1]

N. A. ORESHKINA, V. V. Dokuchayev Soil Institute Academy of Sciences, USSR

In this article we report on the results of studies on the water-retaining capacity of soils, conducted on separates.

In a preceding paper (5) we reported the results of a study of the water-retaining capacity of sands (particles 0. 25-0. 20 mm in diameter), as follows:

1. When moisture does not exceed minimum moisture capacity (NV)[2], the moisture in the sand cannot move to the evaporating surface as a liquid. Therefore, in columns composed of particles about 0. 25 mm in diameter or larger, moisture corresponding to minimum moisture capacity occurs as isolated accumulations ("cups"); i. e. it appears to be a wedge.

2. When moisture even slightly exceeds the NV, the moisture in the sand acquires capillary continuity and can migrate to the evaporating surface as a liquid.

3. A layer of capillary-suspended moisture is retained in the originally dry sand when moisture approaches full moisture capacity. This can be explained by the action of different capillary tensions of the upper and lower surfaces of the menisci delimiting this layer, and by wetting hysteresis. Our experiments agreed with this currently universally adopted explanation (6).

The experimental method used with the 0. 10-0. 08 and 0. 05-0. 03 mm diameter fractions was basically the same as that used with the 0. 25-0. 10 mm fraction.

Poured columns, each consisting of a glass tube about 3 cm in diameter filled with the respective fraction, were used in the tests. Materials were placed in the tubes in a dry state, tamped down and then moistened with 0. 1 N solution of calcium chloride. Two series of experiments were performed on each fraction: a) continuous soaking; b) partial wetting, the lower part of the column remaining dry.

In both cases we studied the equilibrium of the moisture distributed in the columns and its movement during the process of evaporation from the surface of the column or in the process of draining (in incomplete saturation).

We shall now examine the results of experiments on the 0. 10-0. 08 mm diameter fraction. Curve 5 in Figure 1 shows the moisture distribution in a 2 m column after thorough soaking and after the excess solution was drained off.

Moreover, the moisture was in a state of equilibrium since not a single drop of the solution drained from the lower end of the column over a period of several days. Evaporation from both ends of the column was eliminated; moisture was drained into a covered flask. Thi curve, as well as that obtained in experiments with the 0. 25-0. 20 mm diameter particles (Curv 7, Figure 1), is capillary in nature and can be divided into three parts according to the degree of moisture. The lower zone of full moisture saturation is about 50 cm thick and its moisture 28%-29%, which corresponds to the full moisture capacity of this fraction (when the bulk density is 1. 50). The thickness of the next zone, which is transitional as far as moisture is concerned (the moisture content decreases toward the top from 28%-29% to 3. 5%-4%) is approximately 80 cm. The thickness of the entire capillary continuity in a column of 0. 10-0. 80 m diameter particles is approximately 130 cm. The thickness of the upper zone of low moisture content varying between 4% and 2. 5% is approximately 80 cm in this case.

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[1] Work performed under the direction of Professor A. A. Rode.

[2] Abbreviations used: NV - minimum moisture capacity; PV - full moisture capacity; VRK - discontinuous capillary moisture; VZ - wilting moisture; KK - continuous capillarity; OV - bulk density.

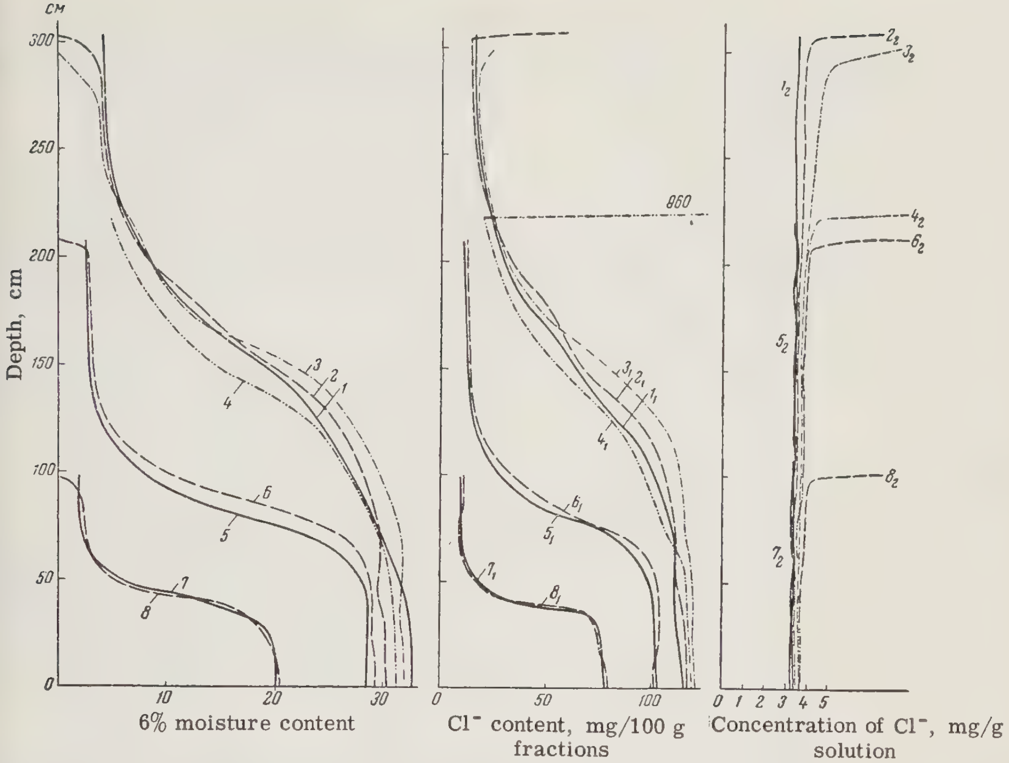

Fig. 1. - The equilibrium and movement of moisture in columns after continuous wetting and cessation of draining.

Particles of 0.05-0.03 mm: 1 - state of equilibrium, bulk density 1.45; 2 - 30-day evaporation, bulk density 1.48; 3 - 30-day evaporation, bulk density 1.34; 4 - 40-day evaporation, bulk density 1.60.

Particles 0.10-0.08 mm: 5 - state of equilibrium; 6 - 20-day evaporation.

Particles 0.25-0.20 mm: 7 - state of equilibrium; 8 - 20-day evaporation.

To explain the behavior of moisture in this one during evaporation, experiments were conucted by evaporating the $CaCl_2$ solution from the olumn. In Figure 1, curves 5, 5_1 and 5_2[3] repesent the respective moisture, the Cl$^-$ perentage, and its representative concentration efore evaporation (i. e. in a state of equilibrium). urves 6, 6_1 and 6_2 represent the same properes, but after a 20-day evaporation of moisre from the column.[4]

All curves are based on average data taken rom two or three parallel experiments. As e diagram shows, there is no accumulation of Cl$^-$ in the evaporation zone. We therefore conclude that there is no movement of moisture in a column of 0. 10-0. 08 mm diameter particles when the moisture content is 2. 5%-3. 5%. Hence, in these columns, moisture in the zone above the capillary content is a contact phenomenon as it is in the case of the 0. 25-0. 20 mm diameter fraction. Such capillary discontinuity of the moisture was observed with the various degrees of compaction of the particles caused by the significant size of the particles and interstitial spaces compared to the diameter of the contact "cups."

When columns of 0. 10-0. 08 mm diameter particles are incompletely moistened (no evaporation from their surface), moisture retention depends on the thickness of the moistened layer and the degree of compaction of particles in the column (Figure 2b). When moistened with no more than 100 mm depth of water and when the particles are loosely packed (bulk density no more than 1. 40), moisture is retained in suspension in a continuous layer by capillary

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Curves 5_2 and 7_2 are practically identical to the orresponding sections of curve 1_2.

[4] Moisture and Cl$^-$ retention were determined in fferent columns but they were simultaneously and entically prepared. The state of equilibrium was onsidered established within 10 days after the column as wetted (i.e., after cessation of solution adsorpon).

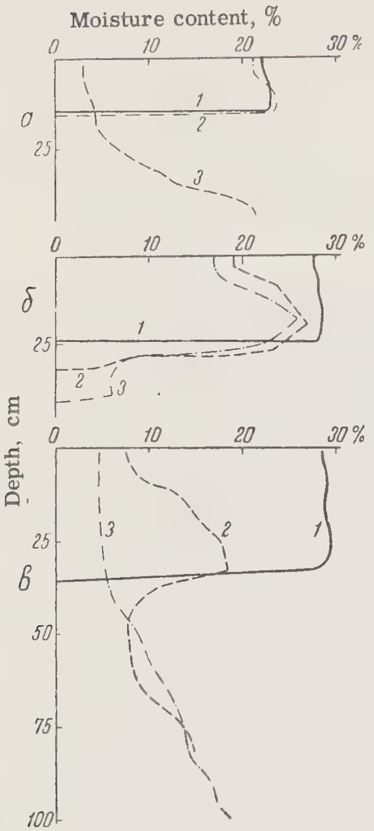

Fig. 2. - Distribution of capillary-suspensed moisture in sand.

a. Particle diameters - 0.25-0.20 mm, bulk density 1.65, depth of solution, 50 mm: 1 - Original condition; 2 - After 20 days; 3 - Amount of solution 100 mm - after 10 days.

b. Particle diameters - 0.10-0.08 mm, depth of solution, 100 mm: 1 - Original condition; 2 - After 10 days, bulk density 1.35; 3 - After 40 days, bulk density 1.45.

c. Particle diameters - 0.10-0.08 mm, depth of solution, 150 mm: 1 - Original condition; 2 - After 10 days, bulk density 1.50; 3 - After 20 days, bulk density 1.50.

action (although an occasional percolation can be observed even in this case). The moistened zone is 22-24 cm thick and its moisture content approaches full moisture capacity. Using the same amount of water but greater compaction (bulk density 1. 50), moisture slowly percolates (drains or is resorbed) down the column. Below the original wetted layer, a thin "zone of resorption" forms, in which the moisture content is about 5%-6%, and which has a sharply-defined lower moisture contact. By way of comparison we show the distribution of capillary suspended moisture in columns of 0. 25-0. 20 mm diameter particles when various quantities of solution were added (Figure 2a).

When a large amount of moisture is applied to the surface of a column (150 mm depth of water) consisting of 0. 10-0. 08 mm diameter particles, this moisture moves to the bottom of the column within a few days, the drainage occuring not in tongues but as a front. (Figure 2c).

Thus, 0. 10-0. 08 mm diameter particles are an example of the upper limit at which signs of capillary resorption appear. Evaporation of capillary-suspended moisture from 0. 10-0. 08 m diameter particles is shown on Figure 3a. The accumulation of Cl^- indicates the intensive attraction of the fluid moisture toward the zone of evaporation. It is interesting to observe that some accumulation of Cl^- as well as an increase in its concentration also occurred at the lower limit of wetting. This indicates a small amount of evaporation of moisture in the interstitial spaces. It should be emphasized that drainage of moisture was never observed when evaporation was taking place.

We shall now report on the results of experiments on 0. 05-0. 03 mm diameter particles. Curve 1 in Figure 1 illustrates the equilibrium distribution of moisture in a 3 m column. This curve differs markedly from the two analogous curves for the larger fractions. Particularly noticeable is the extensive expansion of the transitional zone and the very ill-defined contacts between the zones. The zone of full saturation here is about 50 cm thick with a moisture content of 32%-33% (bulk density 1. 40-1. 45).

The thickness of the transitional zone where moisture content decreases from bottom to top from 32% to 4. 5%-5%, is 180 cm and that of the entire capillary contact is 230 cm. The thickness of the zone of low moisture content is 60-70 cm in the 3 m column.

To determine in which form, wedges or continuous capillary, moisture is retained in the upper portion of tall columns, we conducted evaporation experiments with particles of this fraction. Evaporation occurred without heating the surface of the column, i. e. the entire colum was kept at the same temperature (about 20° C). Figure 1, Curve 2 shows that when bulk density was 1. 48, we observed a small accumulation of Cl^- at the evaporating surface, i. e. there was movement of a small quantity of moisture from the underlying layers to the area of discontinuity. This was observed in all cases when the bulk density was not less than 1. 40. We therefore have a basis for the assumption that with the given particle size and with approxi-

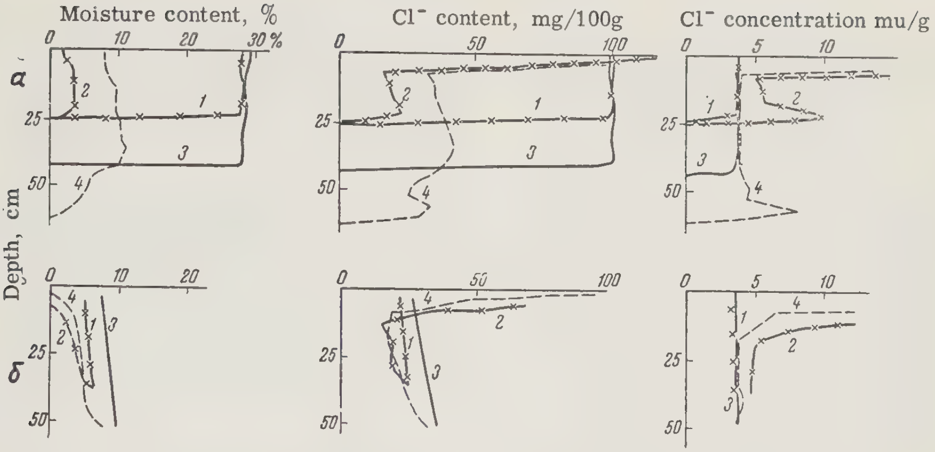

Fig. 3

a - Evaporation of capillary-suspensed moisture from zones of high moisture content.

Particle diameters - 0.10-0.08 mm: Depth of solution 100 mm: 1 - Original condition; 2 - 80-day evaporation.

Particle diameters - 0.05-0.03 mm: Depth of solution 200 mm: 3 - Original condition; 4 - 40-day evaporation.

b - Evaporation from resorption zones.

Particle diameters - 0.05-0.03 mm: 1 - Original moisture content 5%; 2 - 40-day evaporation; 3 - Original moisture content 7%; 4 - 50-day evaporation.

ately 5% moisture, the contact "cups" are onnected by films (bridges) of moisture capble of moving as a liquid. These films are asily destroyed by moisture discontinuity. herefore, the flow of moisture to the evaporaon area depends on the compaction of the parcles. In loosely packed columns (bulk density 1. 35) the Cl⁻ accumulation was very small Figure 1 curve 3). When 0. 05-0. 03 mm dimeter of particles were loosely packed conitions for moisture retention approached ose for larger particles.

What is the nature of the films (bridges) unitg the contact "cups?" Undoubtedly, we are ealing here with the co-existence of menisci d films. Films consisting of very loosely ound (or possible free) moisture do not move der the action of gravity, since they are in uilibrium with the free moisture of the mensci. According to several investigators (2, 3, when thin films cover the surface of the il particles (excluding the films of solidly ound water) there occurs in them an "outushing pressure" which depends on the thickess of the film. In the column at a given height, the force of gravity, the outpushing pressure d the capillary forces of the menisci are ual, the film does not drain off.

Our experiments showed that with particles rger than 0. 05 mm diameter the moisture the upper areas of tall columns can be wedge oisture only, because the dimensions of the interstitial spaces are sufficiently large with respect to the dimensions of the "cups" so that after the remaining "gravitational" moisture runs off, the "cups" become isolated from each other. One can imagine that in columns composed of particle diameters larger than 0. 05 mm the films (bridges) of movable moisture between the separate "cups" are fairly "long" and "thick" but their sorption forces are so small that they cannot counteract the force of gravity and the tension force of the menisci. Therefore, with low moisture content (about minimum moisture capacity), these films break and the moisture creeps under the menisci and down the column. With particles smaller than 0. 05 mm in diameter the films are very thin and may remain on the particle surfaces as demonstrated earlier.

We will now turn our attention to the phenomenon of moisture decrease occurring in the column from the bottom to the top of the zone located above the upper limit of the continuous capillarity. If it is true that moisture in this zone exists in the form of "cups" (regardless of whether they are isolated or connected by bridges) then the decrease in moisture content must be associated with the decrease of the diameter of the "cups." This phenomenon was experimentally demonstrated by Melnikova's experiments with spherical particles 1 mm in diameter (4). In these experiments the curves for the changes in the diameter of the "cups" are very similar to the moisture distribution curves in our experiments.[5] The largest "cups" should occur at that moment when there is marginal contact. This means that the film between adjacent "cups" disappears and moisture in the interstitial space is restrained by menisci only. In the column this condition corresponds to the upper limit of the continuous capillarity and a moisture content of about 5%-6%. Even so, with a moisture content of 5%-6% and higher, moisture in the 0. 05-0. 03 mm diameter fraction should always (i. e., at any bulk density) occur in the continuous capillarity state. Evaporation of moisture from the upper portion of the continuously capillarity (from a 220 cm column, Figure 1, Curves 4, 4_1 and 4_2) confirmed that a rapid upward movement of moisture occurs here. It is clear that the lower the layer in the column, the more the interstitial spaces will be filled with water and that, finally, in the zone where the moisture content equals the full moisture capacity, water fills all insterstitial spaces with the exception of trapped air pockets.

Chains of interstitial spaces completely saturated with moisture extend upward from the upper limit of the zone of full moisture capacity. The farther from this contact, the fewer the chains. Along with them, at the same depth, there are interstitial spaces which are not completely filled with water, but in which the "cups" have merged.

In the upper half of the continuous capillary, moisture exists probably only as merged "cups." This in itself guarantees great mobility.

We now turn to experiments involving partial wetting of columns 0. 05-0. 03 mm diameter particle. Columns of air-dried silt were moistened from the top with varied quantities of the 2 cm depth of solution. The quantity of solution used in the various experiments corresponded to depths of 50, 100, 150, 200 and 300 mm. The moisture capacity in the columns was determined both immediately after the solution was absorbed (initial condition) and at various time intervals when there was no evaporation. The distribution of moisture in the columns is shown in Figure 4.

In all cases initial moisture capacity approached full moisture capacity. Further moisture movement depended primarily on the quantity of the solution introduced at the surface of the column. When a depth of 50 mm of solution was used (Figure 4a) moisture was retained by capillary suspension, interstitial spaces were fully saturated and almost no resorption took place. When a 100 mm depth of solution was used a slight resorption (or drainage) was observed, and the zone of resorption was thin. With 150 and 200 mm depths of solution (Figures 4g and 4d) drainage was observed. This decreased with time but did not cease entirely even in a 150-day period. When the solution depth was 300 mm (Figure 4e) a fairly fast, nearly constant, frontal drainage of moisture occurred.

The nature of moisture retention is also strongly affected by the degree of compaction as well as by the quantity of solution used. When compaction was dense moisture drainage was usually faster than when it was loose. In other words, loose compaction of particles results in conditions of water retention analagous to those found in columns of larger particles.

It is interesting to observe the effect of surface character of particles on the intensity of capillary resorption.

Some investigators believe that the absence of capillary resorption in sand and its marked presence in silt can be explained by the rough surfaces of silt particles as compared to the smooth surfaces of sand particles. Apparently the nature of the particle surfaces has some importance here, but is not decisive. In our experiments particles of various dimensions, but essentially identical in surface character, were used, and yet the degree of capillary resorption varied. The controlling factor in this respect is the various diameters of the particles and the density of compaction, i. e., in the final analysis, with the size of the interstitial spaces in the column. Capillary resorption becomes apparent in columns of 0. 1 mm diameter of particles and increases with decrease in diameter and increase in degree of compaction.

We will now consider the details of moisture behavior in columns with particles of the 0. 05-0. 03 mm diameter when the solution depth is 200 mm (Figure 4d). After absorption ceases a wet zone 42-45 cm thick is formed in which the moisture content approaches that of full moisture capacity. Immediately moisture movement occurs in the column. Below the initial limit of wetting a zone of resorption forms and the thickness slowly increases at the expense of the moisture of the originally wetted zone. Moreover, in the resorption zone, an almost constant moisture content of 6%-7% is established and retained. Where there is extensive resorption (8 months), it decreases to 5%. This moisture corresponds in amount to the moisture in the upper limit of the continuous capillarity when saturated. The stability of moisture content in the resorption zone indicates that in this zone moisture occupies a definite portion of interstitial space, i. e., there is a constant relationship between the meniscal and gravitational forces which allows a definite moisture volume to be retained in the interstitial spaces.

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[5] See Figure 5 in the paper by Mel'nikova and Nerpin (4).

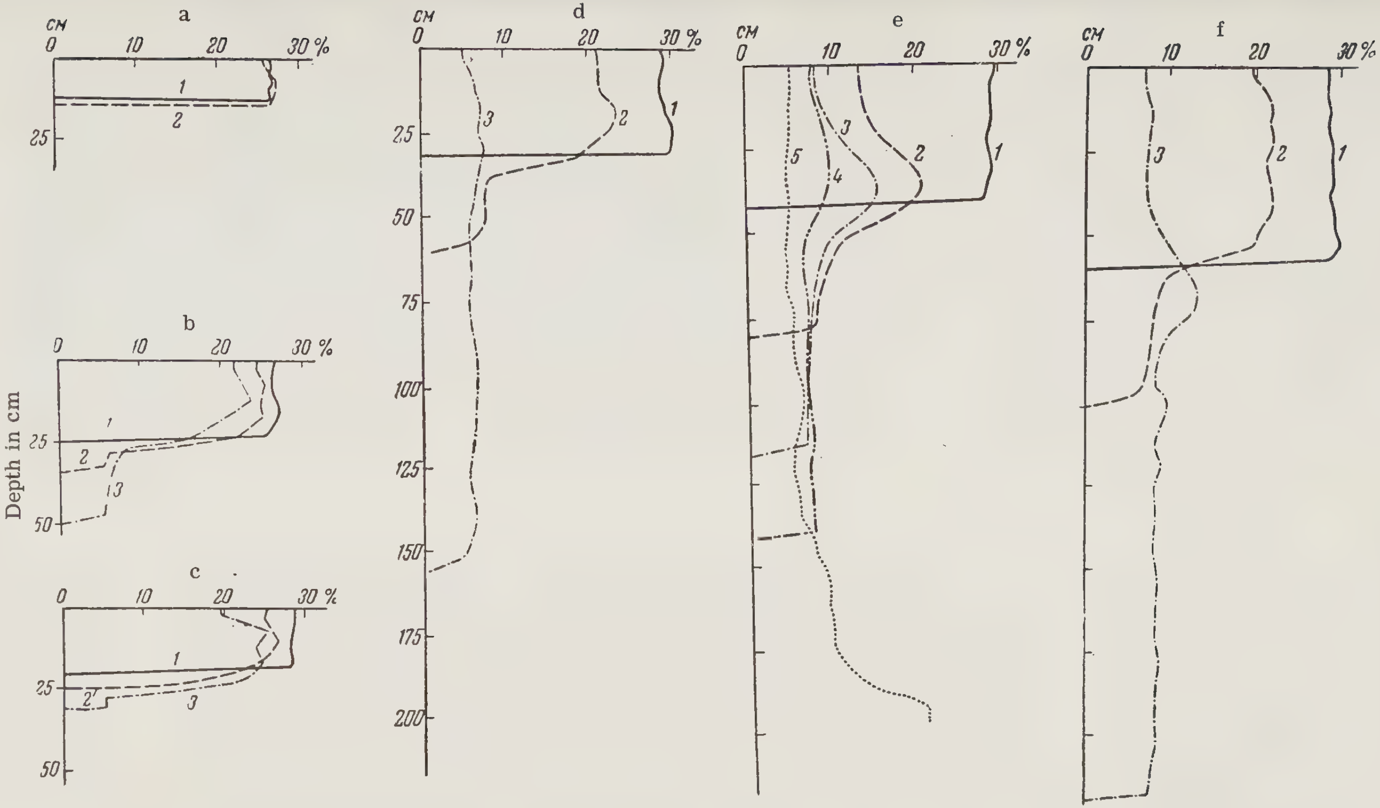

Fig. 4. - Distribution of capillary-suspensed moisture after various time intervals (without evaporation). Particle diameters - 0.05-0.03 mm.

a - Solution depth 50 mm, bulk density 1.50: 1 - original condition; 2 - after 40 days; b - Solution depth 100 mm, bulk density 1.45. 1 - original conditions; 2 - after 10 days; 3 - after 50 days; c - Solution depth 100 mm, bulk density 1.35: 1 - original condition; 2 - after 10 days; 3 - after 40 days; d - Solution depth 150 mm, bulk density 1.40: 1 - original condition; 2 - after 20 days; 3 - after 150 days; e - Solution depth 200 mm, bulk density 1.45: 1 - original condition; 2 - after 10 days; 3 - after 40 days; 4 - after 100 days; 5 - after 8 months; f - Depth of solution 300 mm; 1 - original condition; 2 - after 10 days, bulk density 1.35; 3 - after 10 days; bulk density 1.45.

Apparently, moisture exists in the resorption zone in the form of "cups" with merged surfaces. This moisture slowly percolates from one accumulation to another as a gravitational, circumfluent film. To check whether this moisture is capable of movement in fluid form to discharge area (i. e., whether it is actively continuous capillarity) we set up experiments where evaporation took place from the resorption zone. Figure 3b shows that moisture movement in a fluid state to the place of discharge was fairly intense with a 7% moisture content and was also noticeable at 5%. In time, the evaporating surface moved slightly lower in the column and a layer-by-layer drying of the silt began. This indicates the onset of discontinuity of the capillary bonding between moisture accumulations.

Thus, the experiments indicate that in the resorption zone moisture has the following properties: its volume is constant in a layer of considerable thickness, it has capillary continuity and its drainage is slow. Similar properties are found in the moisture of minimum moisture capacity in loess-like clay loams where particles and microaggregates approximately 0. 05 mm in diameter prevail. One can take the particles of our 0. 05-0. 03 mm diameters as models of micro-aggregates where the moisture of the resorption zone will be analogous to the minimum moisture capacity of clay loams. The value of minimum moisture capacity of our fraction therefore is 5%-6%; this appears to be its upper limit. Its lower limit should correspond to the discontinuity of the capillary bonding between the "cups" which should start at approximately 4% moisture content (when loosely packed). Considering the experiments with continuous wetting, it can also be stated that the minimum moisture capacity in columns containing 0. 05-0. 03 mm diameter particles corresponds to the interval of moisture condition from the moment the "cups" separate from one another, i. e., from the moment their immediate surface connection disappears (upper limit) to the moment when the capillary bonding between the "cups" breaks down, i. e. when their dimensions are decreased to such a diameter that their connecting films lose their mobility (lower limit). In this way the lower limit of minimum moisture capacity is also the upper limit of the moisture content of the discontinuity in capillary bonding (VRK).

The status of the VRK corresponds to that interval of moisture content in which free moisture exists in wedges; its lower limit should correspond practically to the complete absence of "cups" (this would apparently be the wilting). Our experiments have not yet established the limits of VRK. Wilting moisture cannot be caused by drainage in the columns but only by some other moisture movement.

We will briefly consider an experiment dealing with evaporation of suspended moisture from a zone of high moisture content in columns consisting of 0. 05-0. 03 mm diameter of particles (incomplete wetting). Figure 3a, shows the moisture content, Cl^- content and its concentrations at the initial stage and after evaporation. The Cl^- accumulation indicates that a significant quality of moisture movement and evaporation also took place at the lower contact of the wet zone.

Observations showed that during evaporation moisture flow decreased sharply within the first hours and then ceases entirely. It is obvious that the forces attracting the moisture toward the evaporating surface overcame the simultaneous pull of gravity and capillary resorption.

CONCLUSIONS

1. It was determined that the moisture retention mechanism in columns of sorted particles of the same dimensions was determined chiefly by the dimension of the particles and that its character changes when a definite stage of pulverization is reached.

2. After tall columns of 0. 10-0. 08 mm diameter particles were saturated, and excess moisture allowed to drain, a change in moisture condition from capillary-discontinuity to capillary-continuity occurs at 4% moisture content. When moisture content is high, free movement of moisture to an area of discontinuity is possible. With lower moisture contents, free moisture exists only in wedges regardless of the compaction of the particles.

3. When columns containing 0. 10-0. 08 mm diameter particles are incompletely wetted, moisture is retained in capillary suspensed form (moisture content approaches full moisture capacity, normal wetting is no more than 100 mm depth of water, particles are loosely packed and the bulk density 1. 40). Particles 0. 1 mm in diameter are the upper limit beyond which, although slowly at first, the action of the forces of capillary resorption starts.

4. Beginning with 0. 05 mm and smaller diameter particles, moisture in the upper parts of tall columns is in equilibrium, and can exist in a continuous capillarity at 5% of moisture capacity. A necessary condition for this occurrence is sufficient compaction of the particles (bulk density >1. 40).

5. Joining of contact "cups" apparently is accomplished by films (bridges) of very loosely-bonded water which are easily destroyed by moisture discharge. These films

not percolate down the column since the pillary force of the menisci, the forces of olecular attraction of the films to the particle rfaces and the force of gravity, are in uilibrium.

6. We can suggest that the minimum mois- re capacity of the 0.05-0.03 mm diameter rticles corresponds to the 4%-6% moisture ntent interval.

The lower limit of the value for minimum oisture capacity appears to be the upper limit the breakdown of capillary continuity also. sand and in coarse silt (when loosely packed) e minimum moisture capacity and the break- wn of capillary continuity are identical. When lumns containing 0.05-0.03 mm diameter rticles are saturated both a zone of minimum oisture capacity and a zone of breakdown of pillary continuity can exist. Depending on e compaction their thickness can increase or ecrease at the expense of one or the other.

7. In columns of all particles we have udied the moisture content found in the zone wedge moisture decreases regularly upwards om the upper limit of the capillary continuity. his is probably associated with a decrease in e diameter of the contact "cups" along the ngth of the column.

8. The moisture content at which the "cups" e merged (about 6%) corresponds to the upper mit of the capillary continuity in the column. ithin the limits of the capillary continuity the up" margins are always merged. Interstitial aces fully saturated with moisture (continuous ater capillaries) do not extend necessarily to e upper limit of the capillary contact. Ap- rently, they reach a definite height which has t been determined as yet. Merging of the ups" guarantees easy movement of free oisture to its place of dissipation.

9. When columns of 0.05-0.03 mm diameter rticle are incompletely wetted moisture can retained in a capillary-suspensed form (if oisture content approaches full moisture pacity) if the quantity of the wetting solution es not exceed 50 mm depth and if the par- cles are loosely compacted. When a large antity of the solution is used the moisture ains off under the influence of gravity -- the eater the amount of solution, the quicker the w.

One result of moisture redistribution in incomplete wetting is the formation of a zone of capillary, gravitational flow (or a "zone of resorption") with 6%-7% moisture content. This slightly exceeds the minimum moisture capacity of the given fraction.

10. In columns of all the fractions when capillary-suspensed moisture is evaporated from a zone of high moisture content movement of moisture occurs toward the place of evaporation and there is a simultaneous, complete cessation of drainage. Moreover, one can observe evaporation from the lower wetting surface into interstitial spaces.

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FIVE-YEAR OBSERVATIONS OF QUALITATIVE COMPOSITION OF LYSIMETRIC WATER IN VARIOUS TYPES OF VIRGIN AND CULTIVATED PODZOLIC SOILS

YE. I. SHILOVA, Leningrad A. A. Zhdanov State University

The dynamics of moistening soil and the qualitative composition of solutions thus formed are among the most important factors in soil formation.

One of the most widely known methods of studying soil solutions is the lysimetric method which is used in various modifications by many experimental institutes. While not meeting all requirements for a quantitative analysis of solutions percolating through the soil, it can give a certain concept of the intensity of moistening in the soil profile and is valuable in studying quantitative composition of solutions. For this purpose it must be employed in soils with undisturbed structure and with an underformed structural profile, i. e., under natural soil stratified conditions. None of the existing types of lysimeters fulfills these conditions since their installation is inevitably accompanied by a disturbance of the soil, although the extent of deformation may vary. In this respect the least useful lysimeters are the cement-trench and metal box types; their installation is accompanied by a complete destruction of the soil profile. We used a more suitable method -- lysimeters embedded in the soil -- which has the least effect on physical soil properties and makes it possible to obtain practically unaltered solutions from any horizon.

The construction of lysimeters and peculiarities of their operation have been explained by us previously.[1]

Purpose of the Investigation

This paper presents an account of data concerning the quantitative composition of solutions in various types of virgin and cultivated podzolic soils from the period beginning July 1953 through December 1957.[2] The soils studie occur under close relief conditions on one material: reddish gravelly clay loam. The sole difference in the soils consisted in one being virgin soil formed under an 80-100-year-old spruce-oxalidaceae (forest site index of Class 1) while the other was plowland which had been under second year perennial grasses prior to installation of the lysimeters.

The morphological properties and chemical composition of soil of the spruce-oxalidaceae were of the typical strongly podzolized type, while those of the plowland were of the medium podzolized, slightly cultivated type.

Concentration and Composition of Solutions in Strongly Podzolic Soil of the Spruce-Oxalidacea

a). Concentration and composition of the litter solutions (A_0 0-5 cm). One of the pronounced peculiarities of the litter solution is the definitely expressed dynamicity of both its ionic and total concentration, especially the latter (Table 1). The total of ions in it varies from 52. 2-144. 2, and the value of the dry residue from 72-488 mg/l. The solutions which form in the fall through reaction with fresh litter occur in small quantities and have a higher total and ionic concentration. The spring solutions percolating through the litter which has been leached since fall, are greatly diluted by snowmelts and are characterized by insignificant concentration.[3] The degree of the latter is evidently connected not only with seasonal moisture dynamics, but with its periodi-

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[1] Ye. I. Shilova. A method for obtaining soil solution under natural conditions. Pochvovedeniye No. 11. 1955.

[2] O. K. Golovanova, laboratory assistant in agronomy, and K. G. Kreyer and L. V. Korovkina, graduate students, participated in the experimental part of the work.

[3] The test on April 26, 1956 done after the dry fall of 1955, was an exception.

Table 1

Concentration and composition of solutions of litter A_0

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.								pH	Dry residue + $\frac{1}{2}HCO^-$ / Σions	Ca^{++}:Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Σions	Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO^-	$SO_4^=$	Cl^-	Org. acids and NO_3^-			
Fall and winter - 1954																					
Nov. 19	1,0	178,4	14,0	6,4	2,0	Not det	35,6	23,3	5,2	86,5	26,2	19,7	4,1	—	21,7	17,9	5,6	4,8	5,90	2,26	2,18
Dec. 30	0,9	271,2	18,8	8,4	2,3	"	35,4	29,1	6,9	100,9	26,7	19,9	3,4	—	16,5	17,3	5,7	10,5	6,17	2,85	2,24
Spring - 1955																					
May 4	6,0	109,6	9,6	4,2	Not det	Not det	29,1	8,2	2,7	53,9	29,3	20,7	—	—	29,3	10,3	4,9	5,5	5,87	2,30	2,31
May 18	3,0	72,0	8,4	3,5	0,9	"	33,9	3,3	2,7	52,7	28,0	19,3	2,7	—	36,7	4,0	5,3	4,0	5,80	1,68	2,39
Spring - 1956																					
April 26	0,5	356	29,0	10,0	Not det	"	42,7	27,8	34,7	144,2	31,8	18,2	—	—	15,5	12,8	21,7	None	6,10	2,61	2,90
May 16	5,0	150,0	10,5	3,4	1,1	"	18,9	14,8	3,5	52,2	30,2	16,3	3,5	—	18,0	18,0	5,8	8,2	5,55	3,07	3,08
Fall and winter - 1956																					
Nov. 16	0,3	414,8	20,4	6,0	Traces	"	34,8	18,2	17,6	97,0	33,6	16,4	—	—	18,8	12,5	16,1	2,6	6,17	4,69	3,40
Dec. 25	0,3	488,0	22,8	7,2	"	9,2[a]	41,0	29,7	7,1	117,0	29,1	15,1	—	5,1[a]	17,1	15,8	5,1	12,0	6,20	4,34	3,16
Spring - 1957																					
May 6	6,5	183,5	16,2	4,5	0,7	4,1[a]	49,3	16,3	5,2	96,3	31,2	14,3	0,7	3,8[a]	31,2	13,1	5,7	None	6,20	2,06	3,60
Summer - 1957																					
Aug. 21	4,5	173,0	12,8	4,3	Not det	13,9[a]	43,8	13,6	3,3	91,7	23,7	13,3	—	13,0[a]	26,6	10,7	7,0	5,7	7,25	2,13	2,98
Fall - 1957																					
Sept. 19	0,65	224,0	20,0	3,4	"	1,4[a]	42,6	9,5	4,1	81,0	37,9	10,6	—	1,5[a]	26,6	7,6	4,2	11,6	6,00	3,30	5,88
Sept. 28	0,25	125,0	20,8	4,6	"	2,9[a]	49,0	15,6	5,4	98,3	35,4	12,9	—	1,7[a]	27,6	10,9	5,1	6,4	6,09	1,54	4;51

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[a] Data give K^+ content; Na^+ not determined.

Note: Comma represents decimal point.

cally recurrent deviations from the perennial norm. The fall and spring solutions of 1954-1955, formed during greater atmospheric moistening, were less concentrated than those of the following moderately moist period of 1956-1957. Especially great are the changes in the amount of dry residue; the maximum and minimum values were increased approximately twice during the second period. In this respect the fluctuations of ionic concentration are less regular, only its inverse ratio to the degree of dilution is clearly apparent. The greater the volume that enters the lysimeters, the less is the amount of ions.

When there is a small concentration of ions, their composition in the litter solution evidently varies exceedingly. Quantitatively predominating are Ca^{++} Mg^{++} K^+, HCO_3^-, $SO_4^=$, Cl^-, and the anions of organic acids. Individual test analyses have also revealed Fe^{+++}, Fe^{++}, Al^{+++}, NH_4^- , and NO_3^- in small quantities.

The HCO_3^- predominates quantitatively in the anion composition, not only in absolute values, but in many cases in percent equivalents as well. Its percentage participation increases in diluted solutions with low strong acid contents.

In solutions with a higher concentration of mineral and organic acids formed during a moderate moisture period, the participation of the bicarbonate ion decreases.

b). Concentration and composition of the solution of the accumulative humus horizon (A_1 5-17 cm). The sandy loam, slightly humic accumulative humus horizon which overlays a more compact eluvial horizon and is perforated by roots of woody plants, is characterized by a negligible and comparatively stable concentration (Table 2).

The amount of dry residue in the majority of cases varies from 100-200 mg/l. Seasonal variations in this amount are expressed less clearly, but it may be stated that there is a general tendency for solutions formed by snowmelts and during the winter thaws to be more diluted.

Concerning unusual moisture conditions of this horizon, the dynamics of the solution's total concentration were found to be seemingly independent of those in the litter. This was especially evident in the second relatively dry period (1956-1957), when the solution in the litter showed the greatest amount of dry residue, while in the humus horizon the solution was more diluted.

Ionic concentration is expressed on the average by approximately the same values as in the litter: 70-80 mg/l, and the only peculiarities of its dynamics are the lesser range of fluctuations (58. 5-116. 4 mg/l . Seasonal variations in ionic concentration are expressed less markedly. The earlier decrease pointed out in the total concentration of the solution, as compared with the same in the litter, occurs primarily because of organic substances. The ratio of the amount of dry residue to the sum of ions, which characterizes the qualitative composition of the solution, decreased abruptly, especially during the second moderately moist period of 1956-1957, when it decreased to 1. 17-2. 11. During this period the basic components of the solution were ions. Only during the years of increased moisture (1953-1954) did the ratio of the dry residue to the sum of ions increase to 2-2. 5, and even 3. 64 (December 18, 1954), showing the predominance of organic compounds in the solution. In no instance, however, did it attain the high values noted in the litter solution. The quantitatively predominating cations here, as in the litter, are Ca^{++} and Mg^{++}. The composition of anions in the solution is less constant, the ion HCO_3^- being the most frequent among them, both as regards absolute values and percent equivalents. Occasionally, as in the fall of 1954, anions of organi acids appeared in large quantities.

c). Concentration and composition of the solution in the eluvial-illuvial horizon (A_2B 17-50 cm). The A_2B horizon, 30-50 cm in depth, is a compact reddish clay loam with eluvial, light colored bands which descend to a depth of 1 m and deeper in the form of fine streaks. Here the solution front is sharply decelerated, causing all its properties to be modified (Table 3). The figures in Table 3 show an increase in both the total and the ionic concentration of the solution, especially the latter. In all cases ions are the predominating components of the solution; Ca^{++}, Mg^{++}, and HCO_3^- occupy first place in the composition. The ion $SO_4^=$ participates noticeably. Fe^{++}, Cl^-, and K^+ are present in small quantities, but uniformly. In practically all tests the sum of the cations was greater than that of the anions. This indicates a certain content of organic acid salts in the solution, although in the majority of cases the participation of the latter is negligible.

d). Concentration and composition of the solution in the illuvial horizon (B 55-90 cm). Observations were begun in June 1954. The lysimeter was installed in a second, auxiliary position at a depth of 80 cm.

Data obtained (Table 4) show that the total concentration of the solution decreases with transition to the illuvial horizon. The amount of dry residue does not exceed 217. 6 mg/l, and the extent of its fluctuations are greatly reduce The seasonal variations become scarcely noticeable. The basic components of the solution are bicarbonates. Owing to their high content the sum of the ions practically equals the amount of dry residue. In several instances sulfates and chlorides participate noticeably in

Table 2

Concentration and composition of solution in humus-accumulation horizon A_1

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.								pH	$\frac{\text{Dry residue} + \frac{1}{2}HCO_3^-}{\Sigma \text{ions}}$	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	K^++Na^+	HCO_3^-	$SO_4^=$	Cl^-	Σions	Ca^{++}	Mg^{++}	Fe^{++}	K^++Na^+	HCO_3^-	$SO_4^=$	Cl^-	Org. acids and NO_3^-			
Fall - 1953																					
Aug. 20	2,5	178,4	10,5	5,2	Not det	1,0	29,2	20,5	4,1	70,5	27,0	21,1	—	1,9	23,5	20,6	5,9	None	5,70	2,74	2,02
Oct. 7	1,0	198,0	21,2	5,2	"	1,7	71,3	11,5	5,5	116,4	34,0	13,8	—	2,2	37,5	7,7	4,8	"	6,00	2,05	4,07
Spring - 1954																					
March 8	1,5	97,6	10,0	4,8	"	5,5	42,3	14,8	4,1	81,5	22,2	18,0	—	9,8	30,8	13,8	5,4	None	5,80	1,45	2,09
May 17	2,2	142,4	11,6	5,2	"	1,0	20,0	17,8	12,8	70,3	27,6	20,5	—	1,9	15,7	17,6	16,7	"	5,60	2,17	2,23
Fall - 1954																					
Oct. 18	2,5	364,8	35,2	17,2	"	Not det	35,7	13,2	3,5	104,8	27,5	22,5	—	—	9,1	4,2	1,6	35,1	5,60	3,64	2,04
Nov. 19	2,0	225,4	28,4	12,0	0,5	"	17,8	24,5	4,9	88,1	29,1	20,5	0,4	—	5,9	10,4	2,9	30,8	5,49	2,67	2,36
Winter and spring - 1954-1955																					
Dec. 20	1,5	95,2	16,4	7,6	0,8	"	29,7	14,4	5,2	74,1	27,5	21,1	1,4	—	16,4	10,1	5,0	18,5	5,80	1,48	2,16
May 4	7,2	117,6	15,4	6,10	Not det	"	34,0	14,8	2,7	73,0	30,1	19,9	—	—	21,9	12,1	3,1	12,9	5,80	1,84	2,53
May 18	2,8	89,6	11,3	3,3	0,5	"	31,4	8,2	3,8	58,5	32,6	15,7	1,7	—	29,7	9,9	6,4	4,0	5,60	1,80	3,43
Spring and summer - 1956																					
May 16	4,0	121,6	16,7	4,7	0,6	"	26,2	21,3	3,5	73,0	32,2	15,6	1,2	—	17,2	17,6	4,0	11,2	5,84	1,84	3,57
June 25	2,0	116,0	12,2	4,2	Not det	"	21,9	16,2	5,7	60,2	31,8	18,2	—	—	18,7	17,7	8,4	5,2	5,79	2,11	2,90
Winter and spring - 1956-1957																					
Dec. 25	1,7	104,5	10,8	4,6	Not det	2,5[a]	23,2	20,2	6,8	68,1	27,6	19,3	—	3,1	19,2	21,2	9,6	None	5,80	1,17	2,35
May 6	2,8	109,5	19,7	4,9	0,6	3,2[a]	51,7	18,1	3,9	102,1	32,9	13,9	0,7	2,7	28,5	12,4	3,7	5,4	6,07	1,32	4,02
May 22	1,5	146,8	19,9	6,2	Not det	1,2[a]	35,4	32,9	5,2	100,8	32,4	16,6	—	1,0	19,0	22,3	4,5	4,2	Not det	1,63	3,21
Summer - 1957																					
June 7	1,05	143,6	12,0	5,3	"	3,4[a]	35,5	24,6	5,2	86,0	24,4	17,9	—	7,7	23,6	20,8	5,6	None	5,62	1,87	2,26
Aug. 21	1,8	176,0	10,0	5,0	"	7,7[a]	25,7	6,2	5,6	60,2	22,5	18,9	—	8,6	24,1	5,9	6,7	13,3	6,98	3,14	2,00
Fall - 1957																					
Sept. 23	2,1	188,0	9,60	3,4	"	6,2[a]	23,1	21,0	5,4	68,7	25,0	14,6	—	10,4	19,3	22,9	7,8	None	5,54	2,94	2,83
Oct. 7	2,1	96	7,60	3,1	"	6,2[a]	17,6	18,5	4,7	57,7	23,7	16,5	—	10,0	18,2	23,8	8,0	"	5,74	1,82	2,45

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[a] Data give K^+ content, in remaining instances K^++Na^+ computed by difference.

Note: Comma represents decimal point.

Table 3

Ionic composition in eluvial-illuvial horizon A_2B

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.								pH	Dry residue $+\frac{1}{2}HCO_3^-$ / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Σ ions	Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Org. acids and NO_3^-			
Fall - 1953																					
Aug. 28	0,65	201,6	18,8	9,0	Not det	10,0	48,8	28,0	25,0	139,6	22,5	17,9	—	9,6	19,1	13,9	17,0	None	6,08	1,62	2,09
Nov. 19	0,25	280,0	44,0	25,4	"	1,2	209,3	26,3	13,8	320,0	25,2	24,2	—	0,6	39,2	6,3	4,5	"	7,02	1,20	1,73
Spring - 1954																					
May 17	1,2	369,6	38,8	24,8	"	Not det	215,0	9,8	7,0	295,5	24,3	25,7	—	—	44,3	3,2	2,5	"	6,66	1,62	1,57
Fall and winter - 1954																					
Oct. 18	1,0	366,4	55,2	23,5	"	"	250,0	20,6	3,5	352,8	29,2	20,8	—	—	43,6	4,6	1,0	0,8	6,40	1,39	2,35
Dec. 30	0,25	320,0	72,5	33,7	0,5	"	238,0	31,0	3,5	379,2	28,1	21,8	0,1	—	30,4	5,0	0,8	13,8	6,67	1,13	2,15
Spring - 1955																					
May 4	7,2	209,6	33,9	13,4	Not det	"	195,5	14,8	2,7	200,3	30,2	19,8	—	—	39,7	5,5	1,4	3,4	6,43	1,51	2,53
May 18	2,8	158,5	23,3	6,3	1,10	"	72,6	14,7	3,5	120,5	34,5	15,4	0,1	—	35,4	9,2	3,0	2,4	6,03	1,62	3,71
Spring - 1956																					
May 16	2,5	161,6	20,2	6,0	0,10	1,0[a]	48,2	30,4	4,6	110,5	32,6	16,1	0,1	1,2	23,5	20,3	4,2	None	6,32	1,68	3,34
June 25	0,4	97,6	18,8	6,3	Not det	Not det	18,9	21,3	5,2	70,5	32,2	17,8	—	—	10,7	15,4	5,1	18,8	5,90	1,52	2,98
Fall and winter - 1956																					
Nov. 16	0,5	252,5	14,5	6,4	Traces	3,2[a]	Not det	32,9	Not det	—	—	—	—	—	—	—	—	—	6,10	—	2,27
Dec. 25	0,6	205,0	23,3	10,7	Not det	9,2[a]	70,0	28,7	6,7	148,6	25,5	19,5	—	5,0	25,2	13,2	4,1	7,5	6,43	1,61	2,17
Spring - 1957																					
May 6	3,9	225,5	28,0	10,1	0,8	3,7[a]	42,6	35,3	3,9	124,4	29,7	17,8	0,6	1,9	14,8	15,4	2,3	17,3	6,23	1,98	2,77
May 22	1,8	184,0	23,2	7,5	Not det	2,4[a]	50,0	30,3	3,9	117,3	31,5	16,8	—	1,7	22,3	17,1	3,0	7,6	6,27	1,78	3,09
Summer - 1957																					
Aug. 21	1,8	347,0	16,0	6,7	"	60,7	130,0	30,0	35,5	278,9	10,5	7,4	—	32,1	28,3	8,6	13,1	None	6,95	1,47	2,39
Fall - 1957																					
Sept. 19	2,5	146,0	16,4	8,6	"	5,8[a]	63,5	22,1	6,8	123,2	24,2	21,3	—	4,5	30,8	13,6	5,6	"	5,75	1,45	1,91
Oct. 7	2,6	221,0	15,6	7,5	"	6,0[a]	46,6	29,6	6.5	111,8	25,0	19,9	—	5,1	24,3	19,9	5,8	"	6,12	2,18	2,08

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[a] Data give K^+ content; in remaining instances $K^+ + Na^+$ computed by difference.

Concentration and composition of solution in illuvial horizon B

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.							pH	$\frac{\text{Dry residue} + \frac{1}{2}HCO_3^-}{\Sigma \text{ ions}}$	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Σ ions	Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Org. acids			
Fall - 1954																				
Nov. 18	1,0	176,0	18,8	8,0	None	4,5	77,3	15,6	6,8	131,0	26,4	18,6	5,0	35,7	9,0	5,3	None	6,4	1,64	2,35
Dec. 19	1,0	119,2	20,8	6,8	"	1,7	69,0	4,9	15,7	117,2	31,2	16,7	2,1	33,9	3,0	13,1	"	6,3	1,31	3,06
Spring - 1955																				
May 4	3,6	164,8	32,0	9,9	"	10,5	150,0	12,3	4,1	218,8	28,3	12,3	7,4	43,5	4,4	2,1	"	6,4	1,09	3,22
May 18	1,8	123,0	24,4	5,6	"	1,7	62,9	14,9	14,6	122,4	34,9	13,1	2,0	29,4	8,9	11,7	"	6,0	1,26	4,35
Spring - 1956																				
June 25	1,2	107,6	18,8	6,3	"	13,2	97,0	11,5	5,7	152,5	23.6	13,1	13,3	40,0	6,0	4,0	"	6,6	1,03	2,98
Winter - 1957																				
Dec. 25	1,1	121,0	14,7	5,1	"	15,7	88,3	7,40	6,7	137,9	20,5	11,8	17,7	40,4	4,2	5,3	"	6,7	1,20	2,89
Feb. 15	0,25	Not det	Sum of Ca and Mg determined in mg/equiv.		"	12,5	60,6	36,1	7,8		37,4		12,6	25,5	19,0	5,5	"	6,8	—	—
Spring - 1957																				
April 20	2,5	153,5	31,4	6,9	"	17,5	142,0	15,3	6,6	219,8	27,7	10,0	12,3	41,0	5,6	3,4	"	6,7	1,02	4,5
May 22	2,2	152,0	27,6	5,2	"	5,0	88,6	20,5	5,2	152,1	34,3	10,7	5,0	36,2	10,3	3,5	"	Not det	1,29	5,3
Summer - 1957																				
June 7	0,8	198,0	20,0	12,0	"	10,3	114,0	19,7	6,5	182,5	20,4	20,4	9,2	38	8,4	3,6	"	6,38	1,40	1,67
Aug. 21	1,2	202,0	11,6	12,0	"	3,0	53,0	13,2	3,9	95,7	23,0	23,8	3,2	34,9	11,2	3,9	"	7,30	2,39	0,94
Fall - 1957																				
Sept. 19	2,5	200,0	35,2	16,0	"	0,5	150,0	25,1	5,4	232,4	28,3	21,5	0,2	39,3	8,4	2,3	"	6,37	1,19	2,20
Oct. 7	1,1	217,0	20,4	10,1	"	1,6	80,6	21,0	6,0	139,7	26,4	21,8	1,8	34,2	11,4	4,4	"	6,71	1,85	2,02

Note: Comma represents decimal point.

Table 3

Ionic composition in eluvial-illuvial horizon A_2B

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.								pH	Dry residue $+\frac{1}{2}HCO_3^-$ / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	$K^{+}+Na^{+}$	HCO_3^-	$SO_4^=$	Cl^-	Σ ions	Ca^{++}	Mg^{++}	Fe^{++}	$K^{+}+Na^{+}$	HCO_3^-	$SO_4^=$	Cl^-	Org. acids and NO_3^-			
Fall - 1953																					
Aug. 28	0,65	201,6	18,8	9,0	Not det	10,0	48,8	28,0	25,0	139,6	22,5	17,9	—	9,6	19,1	13,9	17,0	None	6,08	1,62	2,09
Nov. 19	0,25	280,0	44,0	25,4	"	1,2	209,3	26,3	13,8	320,0	25,2	24,2	—	0,6	39,2	6,3	4,5	"	7,02	1,20	1,73
Spring - 1954																					
May 17	1,2	369,6	38,8	24,8	"	Not det	215,0	9,8	7,0	295,5	24,3	25,7	—	—	44,3	3,2	2,5	"	6,66	1,62	1,57
Fall and winter - 1954																					
Oct. 18	1,0	366,4	55,2	23,5	"	"	250,0	20,6	3,5	352,8	29,2	20,8	—	—	43,6	4,6	1,0	0,8	6,40	1,39	2,35
Dec. 30	0,25	320,0	72,5	33,7	0,5	"	238,0	31,0	3,5	379,2	28,1	21,8	0,1	—	30,4	5,0	0,8	13,8	6,67	1,13	2,15
Spring - 1955																					
May 4	7,2	209,6	33,9	13,4	Not det	"	195,5	14,8	2,7	200,3	30,2	19,8	—	—	39,7	5,5	1,4	3,4	6,43	1,51	2,53
May 18	2,8	158,5	23,3	6,3	1,10	"	72,6	14,7	3,5	120,5	34,5	15,4	0,1	—	35,4	9,2	3,0	2,4	6,03	1,62	3,71
Spring - 1956																					
May 16	2,5	161,6	20,2	6,0	0,10	1,0[a]	48,2	30,4	4,6	110,5	32,6	16,1	0,1	1,2	23,5	20,3	4,2	None	6,32	1,68	3,34
June 25	0,4	97,6	18,8	6,3	Not det	Not det	18,9	21,3	5,2	70,5	32,2	17,8	—	—	10,7	15,4	5,1	18,8	5,90	1,52	2,98
Fall and winter - 1956																					
Nov. 16	0,5	252,5	14,5	6,4	Traces	3,2[a]	Not det	32,9	Not det	—	—	—	—	—	—	—	—	—	6,10	—	2,27
Dec. 25	0,6	205,0	23,3	10,7	Not det	9,2[a]	70,0	28,7	6,7	148,6	25,5	19,5	—	5,0	25,2	13,2	4,1	7,5	6,43	1,61	2,17
Spring - 1957																					
May 6	3,9	225,5	28,0	10,1	0,8	3,7[a]	42,6	35,3	3,9	124,4	29,7	17,8	0,6	1,9	14,8	15,4	2,3	17,3	6,23	1,98	2,77
May 22	1,8	184,0	23,2	7,5	Not det	2,4[a]	50,0	30,3	3,9	117,3	31,5	16,8	—	1,7	22,3	17,1	3,0	7,6	6,27	1,78	3,09
Summer - 1957																					
Aug. 21	1,8	347,0	16,0	6,7	"	60,7	130,0	30,0	35,5	278,9	10,5	7,4	—	32,1	28,3	8,6	13,1	None	6,95	1,47	2,39
Fall - 1957																					
Sept. 19	2,5	146,0	16,4	8,6	"	5,8[a]	63,5	22,1	6,8	123,2	24,2	21,3	—	4,5	30,8	13,6	5,6	"	5,75	1,45	1,91
Oct. 7	2,6	221,0	15,6	7,5	"	6,0[a]	46,6	29,6	6,5	111,8	25,0	19,9	—	5,1	24,3	19,9	5,8	"	6,12	2,18	2,08

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[a] Data give K^+ content; in remaining instances $K^+ + Na^+$ computed by difference.

Concentration and composition of solution in illuvial horizon B

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.							pH	Dry residue $+\frac{1}{2}HCO_3^-$ / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	Fe^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Σ ions	Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	Org. acids			
								Fall - 1954												
Nov. 18	1,0	176,0	18,8	8,0	None	4,5	77,3	15,6	6,8	131,0	26,4	18,6	5,0	35,7	9,0	5,3	None	6,4	1,64	2,35
Dec. 19	1,0	119,2	20,8	6,8	"	1,7	69,0	4,9	15,7	117,2	31,2	16,7	2,1	33,9	3,0	13,1	"	6,3	1,31	3,06
								Spring - 1955												
May 4	3,6	164,8	32,0	9,9	"	10,5	150,0	12,3	4,1	218,8	28,3	12,3	7,4	43,5	4,4	2,1	"	6,4	1,09	3,22
May 18	1,8	123,0	24,4	5,6	"	1,7	62,9	14,9	14,6	122,4	34,9	13,1	2,0	29,4	8,9	11,7	"	6,0	1,26	4,35
								Spring - 1956												
June 25	1,2	107,6	18,8	6,3	"	13,2	97,0	11,5	5,7	152,5	23.6	13,1	13,3	40,0	6,0	4,0	"	6,6	1,03	2,98
								Winter - 1957												
Dec. 25	1,1	121,0	14,7	5,1	"	15,7	88,3	7,40	6,7	137,9	20,5	11,8	17,7	40,4	4,2	5,3	"	6,7	1,20	2,89
Feb. 15	0,25	Not det	Sum of Ca and Mg determined in mg/equiv.		"	12,5	60,6	36,1	7,8		37,4		12,6	25,5	19,0	5,5	"	6,8	—	—
								Spring - 1957												
April 20	2,5	153.5	31,4	6,9	"	17,5	142,0	15,3	6,6	219,8	27,7	10,0	12,3	41,0	5,6	3,4	"	6,7	1,02	4,5
May 22	2,2	152,0	27,6	5,2	"	5,0	88,6	20,5	5,2	152,1	34,3	10,7	5,0	36,2	10,3	3,5	"	Not det	1,29	5,3
								Summer - 1957												
June 7	0,8	198,0	20,0	12,0	"	10,3	114,0	19,7	6,5	182,5	20,4	20,4	9,2	38	8,4	3,6	"	6,38	1,40	1,67
Aug. 21	1,2	202,0	11,6	12,0	"	3,0	53,0	13,2	3,9	95,7	23,0	23,8	3,2	34,9	11,2	3,9	"	7,30	2,39	0,94
								Fall - 1957												
Sept. 19	2,5	200,0	35,2	16,0	"	0,5	150,0	25,1	5,4	232,4	28,3	21,5	0,2	39,3	8,4	2,3	"	6,37	1,19	2,20
Oct. 7	1,1	217,0	20,4	10,1	"	1,6	80,6	21,0	6,0	139,7	26,4	21,8	1,8	34,2	11,4	4,4	"	6,71	1,85	2,02

Note: Comma represents decimal point.

the composition of the solution, and their volume is usually in inverse ratio to the bicarbonates. No anions of organic acids were found in the composition of this solution. Alkali content, calculated by deficit, increases considerably and evidently at the expense of Na^{++} as the quantity of K^+ by direct determination amounted to only 1. 4-3. 5 mg/l. The ion Fe^{++} was not detected in the composition of cations.

Dynamics in Composition of Solutions in Sod-Podzolic Slightly Cultivated Soil

In 1953, 1954, and 1955 a plowland which adjoined a forest was used as a hayfield. In the fall of 1955 the field was replowed and left fallow until the spring of 1957.

a). Concentration and content of the solution in the arable horizon (A_p 0-18 cm). Cutting of the forest and cultivation of the soil, accompanied by destruction of the litter and the emergence of herbaceous or cultivated plants, create a change in the entire associated soil processes which is usually designated as the replacement of the podzol process by the sod process. The soil solution, which is the direct medium for all biochemical reactions in the soil, should indicate these changes clearly (Table 5).

Attention should be called to the most outstanding peculiarity of the solution in the plowed horizon: its relatively high ionic concentration. In many instances this reaches 200-300 mg/l and more. Mineral salts, primarily the bicarbonates of Ca^{++} and Mg^{++}, are the main components of the solution and determine its total concentration. Organic substances comprise a relatively small part of the compounds in the solution, and the amount of dry residue therefore exceeds the sum of ions but little. The amount of alkali ($K^+ + Na^+$) which occasionally exceeds the Mg^{++} content is shown by the comparatively high characteristics. Direct determination of the K^+ in several tests showed that its concentration changed from 2 to 14 mg/l. In the fall of 1953 and 1954 when the field was under perennial grasses, the $SO_4^=$ was present in large quantities and appeared in inverse ratio to the HCO_3^-. The Cl^- was present as a constant, although its participation in the composition of the solution was usually negligible. After the field was plowed, nitrates appeared in the composition of the solution. It is not impossible that they were present in the solutions obtained prior to this in 1953-1954, but their presence could hardly have been insignificant as the field was then under perennial grasses.

Owing to weather changes, peculiarities of subsoil moisture, dynamics of biological processes in the soil, methods of tilling, etc., and the concentration and composition of the solution in the plowed horizon were subject to considerable fluctuations during the time of observation. For example, in the period from the spring of 1953 to the summer of 1954 solutions were formed which were enriched by free CO_2, bicarbonates, and with a high concentration of ions.

In the summer of 1954, precipitation decreased by almost twice the amount, but fall moisture increased, causing a decrease in free CO_2 and the NCO_3^- to be observed. The ionic concentration, as compared with the corresponding values for 1953, decreased approximately twice. In the spring and the beginning of summer in 1955, during cold, rainy weather the concentration of the solution remained practically unchanged. Its abrupt decrease was observed following the summer dry weather and fall plowing of the field in 1955. The small amounts of solution obtained in the spring of 1956 (May 16), and during the winter thaw (November 25), in both instances formed from snowmelts, showed the smallest concentration of ions and CO_2.

The abrupt increase in the sum of ions during the spring of 1957 was in direct ratio to the irregular temperatures of the winter of 1956-1957. Owing to the formation of ice layers on the soil surface at the end of winter, the solution was formed under anaerobic conditions. In a sample from December 25 the content of free CO_2 amounted to 20. 9 mg/l, while on April 20 it had reached 50. 6 mg/l. The concentration of Ca^{++}, Mg^{++}, and especially HCO_3^- increased by 3 to 4 times as compared with preceding samples, and during this period the ion total and the amount of dry residue attained maximum proportions. The participation of the acid anions in the composition of the solution at the end of spring dropped to minimum proportions.

On the basis of the previous data it may be concluded that the dynamics of ionic concentration here are totally different than in the humus horizon of forest soil. In the spring, dilution of the solution which is characteristic of litter and the humus horizon is completely absent in the plowed layer. The spring samples of 1954, and especially those of 1957, showed a considerably higher concentration than the other spring samples which preceded them.

b). Concentration and composition of the solution in the eluvial horizon (A_2 18-35 cm). As the figures in Table 6 show, the major components of the solution in the eluvial horizon are also bicarbonates of alkali earth, and, to a certain extent, alkali bases. The ratio of the dry residue to the total of ions exceeds that of unity but little. The content of $SO_4^=$ and Cl^- fluctuates greatly, but in the majority of cases is not great. The average ionic concentration

Table 5

Concentration and composition of solution in arable horizon An

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.							Org. acids	pH	Dry residue + ½ HCO_3^- / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-	Σ ions	Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-				
Fall - 1953																					
Aug. 31	3,4	240,0	22,8	6,9	4,7	53,7	33,0	12,4	Not det	133,5	30,0	15,0	5,0	23,2	17,6	9,2	Not det	None	6,09	2,00	3,31
Oct. 7	0,5	271,0	42,8	14,6	14,0	216,0	11,5	5,2	"	304,1	27,3	15,5	7,1	45,2	2,9	1,9	—	"	6,58	1,24	2,93
Spring - 1954																					
May 3	0,5	265,6	34,4	16,8	37,7	255,5	9,8	8,4	"	362,6	18,6	15,1	16,3	45,2	2,2	2,6	—	"	6,28	1,08	2,05
Fall - 1954																					
Oct. 18	3,2	176	14,0	7,6	19,2	91,2	22,2	5,2	"	159,4	16,7	15,0	18,3	35,7	10,7	3,6	—	"	6,35	1,38	1,85
Dec. 30	1,5	136	18,8	8,0	13,0	101,0	19,2	2,5	"	162,5	22,1	15,7	12,2	39,0	9,4	1,6	—	"	6,50	1,15	2,35
Spring - 1955																					
April 21	1,2	135,2	24,1	7,1	6,0	110,0	7,4	2,8	"	157,4	29,6	14,5	5,9	44,3	2,0	3,7	—	"	6,30	1,21	3,39
May 18	0,8	156,5	20,3	6,4	16,7	121,0	6,5	3,4	"	174,3	22,8	10,6	15,1	44,8	3,1	2,2	—	"	6,40	1,24	3,17
Spring - 1956																					
May 16	1,0	91,2	14,4	4,0	8,7	62,7	10,6	5,2	"	105,6	25,7	11,8	12,5	33,7	7,9	5,4	—	"	6,49	1,16	3,60
Fall - 1956																					
Dec. 25	0,15	Not det	21,6	6,2	1,0	58,6	8,2	2,4	27,6	125,6	32,9	15,9	1,2	29,3	5,2	2,1	13,4	"	6,56	—	3,47
Spring - 1957																					
April 20	0,85	278,0	57,5	21,6	13,5	298,9	6,6	4,5	2,8	405,9	27,5	17,3	5,2	47,2	1,3	1,1	0,4	"	6,69	1,05	2,65
May 6	3,25	315,0	63,9	25,0	14,0	304,0	6,6	2,6	2,6	418,7	28,3	18,5	3,2	44,3	1,2	0,7	0,3	3,5	Not det	1,11	2,56
Summer - 1957																					
Aug. 22	0,6	407,0	56,8	25,44	31,9	286,0	50,18	9,38	8,0	467,6	23,4	17,3	9,3	37,8	9,0	2,1	1,1	None	8,38	1,18	2,24
Fall - 1957																					
Sept. 16	0,5	1018	49,6	22,0	3,0	244,4	11,60	5,50	4,0	340,1	27,9	20,7	1,4	45,0	2,7	1,7	0,6	"	7,47	3,35	2,25
Oct. 7	0,3	296	62,4	18,4	8,0	277,0	6,6	6,7	1,2	379,3	32,1	15,6	2,3	46,7	1,4	1,7	0,2	"	6,68	1,15	3,4

Note: Comma represents decimal point.

Table 6

Concentration and composition of solution in eluvial horizon A_2

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.							Org. acids	pH	Dry residue + $\frac{1}{2}HCO_3^-$ / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-	Σ ions	Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-				
Fall - 1953																					
Aug. 31	0,4	251,2	28,0	10,6	24,2	115,0	25,4	29,0	Not det	232,2	21,6	13,5	14,9	29,1	8,2	12,7	Not det	None	6,46	1,33	2,63
Oct. 7	0,5	324,0	41,2	15,1	21,5	174,0	28,0	17,8	"	297,6	24,6	15,1	10,3	34,3	9,6	6,1	"	"	6,20	1,3	2,73
Spring - 1954																					
May 3	0,2	Not det	32,0	13,0	24,0	185,9	14,9	9,8	"	279,6	22,0	14,8	13,2	41,9	4,3	3,8	"	"	6,58	—	2,46
Fall - 1954																					
Oct. 18	3,8	364,0	33,0	15,8	4,0	149,0	22,2	7,0	"	231,0	26,4	21,1	2,5	39,4	7,4	3,2	"	"	6,46	1,89	2,07
Dec. 30	0,4	205,3	52,0	14,6	10,5	219,0	5,4	12,0	"	313,5	29,5	15,2	5,3	45,0	3,1	1,9	"	"	6,70	1,00	3,55
Spring - 1955																					
April 21	1,7	396,8	70,8	28,8	25,2	400,0	13,1	4,1	"	542,0	25,4	17,3	7,3	47,2	1,9	0,9	"	"	6,40	1,15	2,46
May 18	5,0	278,0	61,2	24,0	5,5	314,6	3,3	1,7	"	410,3	28,9	19,0	2,1	49,0	0,6	0,4	"	"	6,67	1,06	2,55
Spring - 1956																					
May 16	0,4	168,0	36,4	13,4	1,2	152,0	15,4	5,2	13,0	236,6	30,6	18,6	0,8	38,6	5,4	2,5	3,5	"	6,78	1,03	2,72
Fall - 1956																					
Dec. 25	0,35	206,0	41,8	14,5	0,5	183,5	20,3	19,6	7,6	287,8	31,5	18,2	0,3	33,2	6,6	8,4	1,8	"	Not det	1,03	2,88
Spring - 1957																					
May 6	2,0	205,5	42,3	20,2	3,7	204,0	20,0	5,2	1,6	297,0	26,8	21,2	2,0	44,2	2,5	2,0	0,3	1,0	"	1,03	2,09
May 22	0,28	Not det	50,0	19,8	26,0	260,5	26,2	6,5	12,1	401,1	24,1	15,9	10,0	41,1	5,3	1,7	1,9	None	6,61	—	2,53
Fall - 1957																					
Sept. 23	2,5	370	66,4	31,0	3,1	354,0	7,0	3,7	Traces	465,2	27,5	21,4	1,1	48,0	1,1	0,9	0,0	"	0,60	1,18	2,14
Oct. 7	0,4	366	62,4	30,4	3,4	329,0	7,4	6,0	0,0	438,6	27,2	22,0	0,8	46,5	1,3	1,5	0,0	,7	6,98	1,22	2,05

Concentration and composition of solution in illuvial horizon B

Date	Vol. of solution, liters	Dry residue, mg/l	mg/l								percent-equiv.							pH	Dry residue $+\frac{1}{2}HCO_3^-$ / Σ ions	Ca^{++}: Mg^{++}
			Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-	Σ ions	Ca^{++}	Mg^{++}	$K^+ + Na^+$	HCO_3^-	$SO_4^=$	Cl^-	NO_3^-			
Fall - 1953																				
Aug. 20	2,5	391,2	63,0	34,0	8,7	312,0	20,6	27,7	Not det	466,0	24,8	22,4	2,8	40,4	3,4	6,2	Not det	6,78	1,16	1,85
Aug. 7	2,5	355,5	78,4	21,8	9,5	393,0	14,8	8,0	"	525,5	28,1	19,0	2,7	46,2	2,2	1,6	—	6,40	1,05	3,60
Spring - 1954																				
May 17	1,7	333,6	66,8	32,0	12,5	344,0	11,5	4,0	"	470,8	27,8	18,1	4,1	47,0	2,0	1,0	—	6,68	1,07	2,09
May 26	1,9	376,8	81,2	40,4	None	427,0	11,5	6,2	"	566,3	27,3	22,7	—	47,2	1,6	1,2	—	6,58	1,04	2,01
Fall - 1955																				
Oct. 18	5,0	305,5	52,4	24,8	1,7	250,0	24,7	5,2	"	358,8	27,6	21,7	0,7	43,2	5,3	1,5	—	6,70	1,20	2,11
Nov. 19	2,9	252,0	52,0	22,5	None	250,0	15,6	1,7	"	341,8	29,1	20,9	—	45,9	3,6	0,5	—	7,10	1,11	2,31
Spring - 1955																				
April 21	7,7	292,0	65,4	27,4	1,0	320,0	11,5	2,8	"	428,1	29,2	20,4	0,4	47,2	2,1	0,7	—	6,65	1,05	2,39
May 4	7,8	172,0	35,0	15,1	2,5	170,0	6,6	2,8	"	232,0	28,2	20,2	1,6	44,7	4,0	1,3	—	6,47	1,11	2,32
June 14	2,0	286,0	71,2	27,4	None	324	13,1	2,8	"	438,5	30,4	19,6	—	45,5	2,3	0,7	—	6,80	1,02	2,60
Spring - 1956																				
May 16	1,2	224,8	40,8	18,0	—	222,0	Not determined				—	—	—	—	—	—	—	Not det	—	2,27
June 26	0,8	241,6	42,2	22,7	15,0	276,6	19,7	5,0	Not det	352,2	22,9	20,6	6,5	44,1	4,4	1,5	—	6,91	1,07	1,86
Fall - 1956																				
July 25	1,8	314,0	43,2	24,8	6,7	234,5	15,6	7,7	2,1	334,6	24,0	23,0	3,0	42,8	3,6	3,3	0,3	7,3	1,29	1,74
Spring - 1957																				
Feb. 15	1,6	225,0	43,3	27,1	6,2	256,0	12,3	10,5	1,8	357,2	22,7	23,5	3,8	43,9	2,7	3,1	0,3	7,0	1,15	1,59
May 22	1,5	238,0	46,8	22,8	None	232,0	10,7	3,9	6,7	322,9	27,5	22,5	—	44,8	2,6	1,3	1,3	Not det	1,09	2,04
Summer - 1957																				
Aug. 22	0,2	578,0	92,0	56,4	5,0	524,0	35,0	6,0	—	718,4	24,4	24,8	0,8	45,2	3,9	0,9	—	8,38	1,17	1,64
Fall - 1957																				
Sept. 16	2,5	623,0	70,4	34,0	3,0	335,5	13,2	15,2	16,0	487,3	27,2	22,0	0,8	42,6	2,1	3,3	2,0	7,89	1,65	2,07
Oct. 28	2,5	388,0	60,0	30,5	2,7	317,0	15,2	5,1	0,0	430,5	26,5	22,5	1,0	46,0	2,8	1,2	0,0	7,01	1,27	1.97

Note: Comma represents decimal point.

of this solution is somewhat greater than that of the plowed layer, and varies from 208. 5 mg/l to 517. 4 mg/l.

The concentration of the HCO_3^- increases from the end of summer until winter. In summer samples taken during August its characteristics are lowest; in fall and winter they increase abruptly, and in spring they attain a maximum. The degree of manifestation of the seasonal dynamics of the HCO_3^- is not the same each year. During 1953-1954, possibly as a result of the limited flow of the solution from this horizon, it appeared less well-defined. In 1954-1955, when the eluvial horizon was continually moistened excessively and the flow of solutions was especially great, the seasonal dynamics of concentration of the solutions were most clearly manifest.

c). Concentration and composition of the solution in the illuvial horizon (B 35-80 cm). In the illuvial horizon, characterized by a more regular and abundant flow of the solution in the lysimeter, the amount of dry residue and the total of ions are not subject to such abrupt fluctuations as is the case in the upper horizon of the profile (see Table 7) The maximum concentration of ions (566. 3 mg/l) exceeds the minimum (232. 0) approximately twice, whereas in the plowed layer this ratio reached 4. 5, and in the eluvial, 2. 5 to 3. 0. The seasonal dynamics of concentration are not clearly expressed.

The quantitatively predominating components of the solution which determine its properties and dynamics are the Ca^{++} and Mg^{++} bicarbonates with a lesser $Ca^{++}:Mg^{++}$ ratio. The presence of other salts in the composition of the solution is insignificant, and in this respect the solution of the illuvial horizon differs noticeably from those of the upper horizons which not infrequently contain considerable quantities of alkalis and sulphates. Other peculiarities are the comparatively low content of free CO_2 which fluctuates between 10. 3-61. 5 mg/l, a lesser acid reaction, which approaches neutrality, and the complete absence of Fe^{++}, even as traces. In ionic composition this solution approximates closely the solution of the illuvial horizon of forest soil, but differs from the latter by its higher concentration. Both are evidently connected with ground waters and are derivatives of them.

Thus, the soils investigated, with similar composition of solutions in the lower horizon o the profile, differ substantially in their properties and dynamics in the upper horizons which are influenced directly by the plant cover and the hydrothermal system created by it.

As a result of the combined action of all factors beneath forest growth, solutions are formed with a high organic content and a low ionic concentration. The amount of dry residu which more exactly expresses the total concentration of these solutions varies with time, the amount of litter fall, and weather conditions. During fall samples it is usually greater than during the spring when the solutions are greatl diluted by snowmelts. The volume of mineral salts is insignificant.

Owing to the negligible intake of plant materials and the absence of litter, the solutions of the upper horizons in cultivated soils contain little organic matter. Their quantitatively predominating components are the alkali base bicarbonates which form under conditions of organic gas interchange and carbon dioxide reaction with adsorbed cations. Therefore the total ions, a more exact characteristic of the solution in cultivated soil, increases regularly during the fall-winter period, and especially during the spring when ice forms. In the summer, owing to the vigorous gas interchange an the loss of free CO_2, the bicarbonates decompose, causing the concentration of the solution to abruptly decrease. Beside the previously mentioned differences in the solutions of the soils investigated, there exist certain similarities in their contents and dynamics. For example Ca^{++}, Mg^{++}, and HCO_3^- predominate quantitatively in the ionic composition of both forest and cultivated soils. In the lower horizons of both soils, as pointed out previously, there are formed solutions which are practicall identical in composition with high bicarbonate contents.

The data obtained thus indicate a close genetic relationship between soil and ground water and point to the direct participation of the latte in creating fertility in podzolic soils.

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ATER STABILITY OF AGGREGATES OF CHESTNUT SOILS
THE VICINITY OF THE TSIMLYANSKIY RESERVOIR

A. PCHELIN, Voronezh Forest Institute

The development of extremely effective asures to control soil erosion and prevent reservoir from becoming silted is of pri- ry importance for increasing productivity the Tsimlyanskiy Reservoir Basin.

We have studied the water stability of ag- egates and other properties which determine relation of chestnut soils to water over a e-or-more-kilometer-wide coastal strip.

The non-eroded and eroded varieties of k-chestnut, chestnut and light-chestnut ls most prevalent in the reservoir basin were objects of study. Studies were replicated ee times with an accuracy commensurate h the methods used.

A description of the morphological features chestnut soils in the Tsimlyanskiy Reser- r Basin follows.

Dark-Chestnut Soil

Profile No. 26. Laid out on the water divide teau (Pyatiizbyanskaya station, Kalachev- y rayon, Stalingradskaya Oblast').

A_1 0-14 cm. Dark-chestnut, fine clay loam, cky, friable, fresh. Pierced by plant roots. ansition to following horizon gradual.

A_2 14-22 cm. Chestnut, fine clay loam, cky with presence of lamination, compact, . Fewer roots than in preceding horizon. ansition to following horizon gradual.

B_1 22-42 cm. Brown, fine clay loam, sm-like to blocky, dense, dry. Few roots. nsition to following horizon gradual.

B_2 42-80 cm. Yellow-brown with brown eaks, fine clay loam, nutty to prism-like, remely dense, dry, a clearly expressed te flecks. Very few roots. Transition to owing horizon-gradual.

BC 80-105 cm. Yellow-brown, medium clay loam, blocky, extremely dense, dry. Solitary roots and a rare white flecks occur. Transition to following horizon gradual.

C 105-115 cm. Yellow-brown, coarse clay loam, carbonate, structureless, depth of effervescence 42 cm.

Chestnut Soil

Profile No. 51. Laid out in the center of a strongly sloping soil area (the Nagavskaya station, Kotel'nikovskiy rayon, Stalingradskaya Oblast').

A 0-20 cm. Chestnut, fine clay loam, blocky to laminar, compact, fissured, dry. Pierced by plant roots. Transition to following horizon gradual.

B_1 20-40 cm. Brown with cinnamon shade, fine clay loam, prism-like, extremely dense, fissured, dry. Few roots. Transition to following horizon gradual.

B_2 40-75 cm. Light-brown, clay, prism-like to nutty, extremely dense, dry. A clearly expressed white flecks. Transition to following horizon gradual.

C 75-100 cm. Yellow-brown, clay, structureless, dense, carbonate, depth of effervescence 30 cm.

Light Chestnut Soil

Profile No. 43. Laid out in the upper part of a plateau-shaped, strongly sloping area (the Il'men'-Suvorovskiy farmstead, Voroshilovskiy rayon, Stalingradskaya Oblast').

A 0-15 cm. Light-chestnut, fine clay loam, laminar to blocky, compacted, moist. Plant roots occur in large number. Transition to following horizon noticeable.

B_1 15-28 cm. Brown with light-brown tongue-like projections, fine clay loam, prismlike, dense, dry. Few roots. Transition to following horizon gradual.

B_2 28-68 cm. Light-brown, fine clay loam, nutty, extremely dense, dry, clearly pronounced white flecks. Very few roots. Transition to following horizon gradual.

BC 68-105 cm. Yellow-brown, fine clay loam, blocky to structureless, dense, dry. Isolated roots occur.

C 105-120 cm. Yellow-brown, fine clay loam, loess-like, carbonate clay loam. Depth of effervescence 25 cm.

In contrast to uneroded chestnut soils the eroded chestnut soils have a more shallow soil profile.

In the slightly eroded soils not more than one-half of the humus horizon has been removed; in the moderately eroded soils more than one-half or even the entire humus horizon has been removed. In the severely eroded soils not only the humus horizon but also, partly, the B horizon has been removed.

The zone of effervescence in the eroded soils has been found to be higher than in the non-eroded soils.

The chestnut soils in the Tsimlyanskiy Reservoir Basin have a fine clay loam, silty to clay or clay to silty texture (Table 1).

The chestnut soils in the Tsimlyanskiy Reservoir Basin are soils of comparatively low humus content. The humus content (Table 2) in the upper horizon varies between 2. 84%-4. 53% in the non-eroded soils, 2. 53%-3. 46% in the slightly eroded soils and 1. 61%-2. 49% in the severely eroded soils. In all cases the humus content decreases as we proceed from dark-chestnut to light-chestnut soils and from non-eroded to eroded soils. The humus content also decreases with depth.

In most cases hygroscopic moisture (Table 2) decreases with depth. The smallest amount is found in the C horizon. The hygroscopic moisture content in the B_1 and B_2 horizon is higher than in the horizon lying above.

The reaction of chestnut soils varies between neutral and alkaline. (Table 2). They are soils saturated with bases. The exchangeable cations are calcium, magnesium and, in part, sodium (Table 3).

We know that the degree of development of surface erosion of soils depends upon the combined action of a large number of factors, among which the soil structure and character of the aggregate are especially important.

We used Voznesenskiy's and Artsruni's method (2, 6) to study the water stability of aggregates, the dispersion of the soil, its water-retaining capacity and Vilenskiy's (3, 4, and 5) water drop method to examine the erodability of aggregates of a 3-5 mm diameter. The results of this study are found in Tables 4 and 5.

We see from Tables 4 and 5 that: 1. The aggregates of chestnut soils in the Tsimlyanskiy Reservoir Basin are characterized by differences in water stability. Varying amounts of water are required to disperse the aggregates.

2. The water stability of aggregates decreases, as a rule, as we move from dark-chestnut to chestnut and light-chestnut soils and from non-eroded to eroded soils.

3. In the upper horizon the water stability of aggregates of 3-5 mm diameter is lower than in the lower horizon. At the same time the moderately water-stable and non-water-stable aggregates in the upper horizon are usually predominant, while in the lower horizon the water-stable and moderately water-stable aggregates prevail. A small number of highly water-stable aggregates is found in the B_1 horizon of dark-chestnut soils.

Difference in water stability of aggregates depends upon the texture and mineralogic composition of the soil as well as upon the presence of humus and forms associated with the mineral portion of the soil.

To determine the qualitative characteristics of the aggregates of chestnut soils in the Tsimlyanskiy Reservoir Basin, we separated the microaggregates (particles <0. 01 in diameter) in groups I and II from the upper horizon, by using Tyulin's (8, 9) fractional peptization procedure and determined the microaggregate percentages.

Results of the study of the group compositio of microaggregates are given in Table 6. We can see from this table that:

1. The quantity of microaggregates in the chestnut soils is considerable, varying between 37. 59% and 53. 84%.

2. The quantity of group I microaggregates exceeds that of group II microaggregates.

3. The sum of microaggregates decreases a we proceed from dark-chestnut to light-chestnu

Table 1

Particle size analysis of chestnut soils in the Tsimlyanskiy Reservoir Basin
(N. A. Kachinskiy's method)

Soil Group and Location of Profile No.	Horizon and Depth, cm	Percentage of separates (in mm)								
		1—0.25	0.25—0.05	0.05—0.01	0.01—0.005	0.005—0.001	<0.001	Physical Clay <0.01	Silt 0.05—0.001	Physical Sand <0.01
Dark-chestnut (Stalingradskaya Oblast', Kalachevskiy Rayon, Pyatiizbyanskaya Station)	A 0—10	0,90	17,09	32,70	8,94	9,61	30,76	49,31	51,25	17,99
	B_1 27—37	0,37	4,90	42,90	3,20	8,11	40,52	51,80	54,21	5,27
	B_2 57—67	0,66	11,67	28,35	2,48	15,16	41,68	59,32	45,99	12,33
	C 105—115	1,27	62,40	9,88	2,55	5,33	18,57	26,45	17,76	63,67
Slightly eroded dark-chestnut (See No. 26)	A 0—10	7,24	15,70	31,87	5,57	9,81	29,81	45,19	47,25	22,94
	B_1 20—30	6,18	15,40	30,77	3,72	12,69	31,24	47,65	47,18	21,58
	B_2 36—46	4,96	9,06	37,06	4,88	9,02	35,02	48,92	50,90	17,02
	BC 66—76	3,82	17,04	29,94	3,28	9,70	36,22	49,20	42,92	20,86
	C 110—120	4,66	11,59	40,37	4,93	7,62	30,83	43,38	52,62	16,25
Severely eroded dark-chestnut (See No. 26)	B_1 0—8	4,21	19,69	30,74	4,03	7,93	33,40	45,36	42,70	23,90
	B_2 10—20	2,69	12,72	34,07	5,08	9,90	35,54	50,52	49,05	15,41
	BC 30—40	1,65	11,49	33,34	8,64	9,33	35,55	53,52	51,31	13,14
	C 94—104	3,79	13,24	35,59	5,23	10,20	31,95	47,38	51,02	17,03
Chestnut (Stalingradskaya Oblast', Kotel'nikovskiy Rayon, Nagavskaya Station)	A 5—15	0,24	15,41	34,74	5,18	14,83	29,60	49,61	54,75	15,65
	B_1 24—34	0,22	13,21	28,60	9,82	9,05	39,20	58,07	47,47	13,43
	B_2 48—58	0,11	8,88	4,18	29,12	9,77	47,94	86.83	43,07	8,99
	C 90—100	0,08	8,50	22,96	8,60	12,29	47,57	68,46	43,85	8,58
Slightly eroded chestnut (See No. 51)	A 0—14	0,24	1,55	41,10	6,58	9,89	40,64	57,11	57,57	1,79
	B_1 20—30	0,10	8,07	33,04	2,13	8,40	48,26	58,73	43,57	8,17
	B_2 40—50	0,06	7,46	23,86	5,12	12,81	50,69	68,62	41,79	7,52
	C 70—80	0,13	7,57	20,00	7,84	12,98	51,48	72,30	40,82	7,70
Severely eroded chestnut (See No. 51)	B_1 0—14	0,56	0,04	18,65	8,25	13,37	59,13	80,75	40,27	0,60
	B_2 22—32	0,49	5,16	18,19	6,93	13,73	55,50	76,16	38,85	5,65
	C 50—60	0,35	0,66	24,22	7,89	10,01	56,87	74,77	42,12	1,01
Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy Rayon, Il'men'-Suvorovskiy farmstead)	A 0—14	0,25	4,93	41,55	5,80	11,94	35,53	53,27	59,29	5,18
	B_1 17—27	0,14	2,53	38,78	9,79	9,22	39,54	56,55	59,79	2,67
	B_2 37—47	0,11	2,07	39,53	11,20	10,69	36,40	58,29	61,42	2,18
	BC 78—88	0,17	7,67	47,76	3,13	8,59	32,68	44,40	59,48	7,84
	C 120—130	0,15	10,74	38,50	7,65	8,88	34,08	50,61	55,03	10,89
Slightly eroded light-chestnut (See No. 43)	A 0—12	1,62	19,59	28,21	5,15	9,77	35,66	50,58	43.13	21,21
	B_1 18—28	1,56	24,58	25,89	4,90	6,92	36,15	47,97	37,71	26,14
	B_2 40—50	1,13	23,80	21,34	3,06	9,63	41,04	53,73	34,03	24,93
	C 86—96	1,79	30,24	18,13	6,26	9,85	33,73	49,84	34,29	32,03
Severely eroded light-chestnut (See No. 43)	B_1 0—6	10,70	25,13	18,64	5,32	7,03	33,18	45,53	30,99	35,83
	B 16—26	0,09	15,20	35,57	6,33	8,69	34,12	49,14	50,59	15,29
	C 55—65	1,56	5,07	67,96	12,45	4,98	7,98	25,41	85,39	6,69

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e: Comma represents decimal point.

Table 2

Hygroscopic moisture and humus content. pH value of the saline and water extract of chestnut soils in the Tsimlyanskiy Reservoir Basin

Profile No.	Soil group and location of Profile No.	Horizon and depth, cm	Hygroscopic moisture of dry soil, %	Humus content (acc. to Tyurin) %	pH value	
					KCl Extract	Water Extract
26	Dark-chestnut (Stalingradskaya Oblast', Kalachevskiy Rayon, Pyatiizbyanskaya Station)	A_1 0—10	5,15	4,53	6,4	6,9
		A_2 12–22	6,18	3,10	6,1	6,9
		B_1 27—37	6,58	2,17	6,0	6,9
		B_2 57—67	4,91	0,96	7,5	8,0
		C 105—115	3,65	0,81	7,2	8,4
3	Slightly eroded dark-chestnut (See No. 26)	A 0—10	4,10	3,46	7,3	7,6
		B_1 21–30	6,27	2,91	7,4	7,8
		B_2 36–46	5,41	1,17	7,6	8,2
		BC 66—76	4,56	0,70	7,6	8,2
		C 110—120	4,18	0,52	7,6	8,9
2	Severely eroded dark-chestnut (See No. 26)	B_1 0—8	4,11	2,40	7,5	7,7
		B_2 8—20	4,16	1,47	7,5	7,9
		BC 30—40	4,38	1,28	7,6	8,0
		C 94—104	4,32	—	7,6	8,0
51	Chestnut (Stalingradskaya Oblast', Kotel'nikovskiy Rayon, Nagavskaya Station)	A 5—15	5,66	3,19	7,3	7,8
		B_1 21—34	6,79	2,46	7,4	8,1
		B_2 48—58	5,21	1,10	7,7	8,7
		C 90—100	5,72	0,64	7,8	9,0
54	Slightly eroded Chestnut (See No. 51)	A 0—14	6,34	2,74	7,4	7,9
		B_1 20—30	6,00	1,73	7,5	8,1
		B_2 40—50	5,44	1,52	7,6	8,5
		C 90—100	5,87	0,49	7,7	8,4
61	Severely eroded Chestnut (See No. 51)	B_1 0—14	7,59	2,26	7,5	7,9
		B_2 22—32	7,80	1,31	7,4	7,8
		C 50—60	7,95	0,45	7,5	8,2
43	Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy Rayon, Il'men'-Suvorovskiy farmstead)	A 0—14	5,72	2,84	7,6	7,7
		B_1 17—27	5,10	1,78	7,6	8,0
		B_2 37—74	4,04	1,57	7,6	8,0
		BC 73—88	4,17	1,32	7,8	8,5
		C 120—130	4,52	0,42	7,8	8,3
8	Slightly eroded light-chestnut (See No. 43)	A 0—10	5,67	2,53	6,8	7,4
		B_1 18—28	5,83	1,83	7,2	7,8
		B_2 40—50	4,46	0,95	7,7	8,6
		C 86—96	5,33	0,79	7,5	7,8
7	Severely eroded light-chestnut (See No. 43)	B_1 0—6	3,92	1,61	7,6	8,1
		B_2 6—16	4,43	0,65	7,8	8,3
		C 55—65	5,87	0,38	7,7	7,9

Note: Comma represents decimal point.

Table 3

Adsorbed cations of chestnut soils in the Tsimlyanskiy Reservoir Basin
(K. K. Gedroits' method)

Profile No.	Soil group	Horizon and depth, cm	Meq/100 g soil			
			Ca	Mg	Na	Total
25	Chestnut, fine clay loam, clay to coarse silt.	$A_{п}$ 0—10	22,06	10,57	0,53	33,16
		B_1 20—30	25,46	11,22	0,54	37,22
		B_2 32—42	22,97	14,11	1,40	38,49
11	Shallow chestnut, fine clay loam, sandy clay.	$A_{п}$ 0—10	20,0	8,22	0,61	28,83
		B_1 19—28	25,0	9,05	0,82	34,87
76	Light-chestnut, medium clay loam, clay to coarse silt.	$A_{п}$ 0—10	20,41	5,92	0,78	27,11
		B_1 20—30	23,03	10,03	0,96	34,02
56	Light-chestnut, strongly solonetz, medium clay loam, clay to coarse silt.	$A_{п}$ 0—10	14,46	9,62	2,52	26,60
		B_1 12—22	23,04	19,41	6,48	48,89

Note: Comma represents decimal point.

oils and from non-eroded to eroded soils.

Table 7 shows the humus content in the nicroaggregates of Group I and II and in the esidue of the chestnut soils of the Tsimlyankiy Reservoir Basin according to Tyurin's 10) colorimetric procedure.

We see from Table 7 that: 1. The largest oncentration of humus is found in the microggregates of Group I, and only a considerbly smaller amount of humus can be found n the residue and, especially, in the nicroaggregates of Group II.

2. Humus content in the microaggregates f Group I decreases while the humus content n the microaggregates of Group II increases, n the majority of cases, as we proceed from ark-chestnut to light-chestnut soils and rom non-eroded to eroded soils.

The microaggregates, which differ by roup association and humus content, are esponsible for the differences in water staility of aggregates of the chestnut soils in ne Tsimlyanskiy Reservoir Basin, arising rom these microaggregates.

A greater water stability in the structure f dark-chestnut soils, as compared with ght-chestnut soils, as well as greater stailty in the structure of their non-eroded varicies as compared with the eroded varieties re closely correlated with the two kinds of ggregates contained therein which are sharply ifferentiated by their water stability.

One group of water-stable aggregates of hestnut soils consists of humus-enriched icroaggregates from Group I and of mineral particles cemented by free humic acids and humates. Molecules of organic (humus) "cements," as noted by Antipov-Karatayev, and others (1), are related in valence to the external and, in part, to the internal surface of microaggregates and mineral particles. The aggregate which is thus formed, is enriched with humus and is, in the agronomic sense, useful and at the same time more or less susceptible to dispersion and erosion.

Another group of water-stable aggregates in chestnut soils originates from the humus-poor microaggregates of Group II and from mineral particles, without the participation of free humic acids and humates, owing to direct mutual coagulation of high-molecular organic compounds of the fulvic-acid type with free sesquioxides. Molecules of organic matter and of sesquioxides are related in valence to the internal surface of microaggregates and mineral particles. These aggregates are, in the agronomic sense, passive and highly resistant to dispersion and erosion.

The microaggregates of Group I are responsible for the presence of a water-stable structure in the chestnut soils of the Tsimlyanskiy Reservoir Basin. Owing to their small quantities, the microaggregates of Group II are not a decisive factor in the formation of a water-stable structure. As noted previously, the percentage of Group I microaggregates and their humus content in the chestnut soils of the Tsimlyanskiy Reservoir Basin decrease as we proceed from dark-chestnut to light-chestnut and from non-eroded to eroded soils. Consequently, the water-stability of the structural fragments is lowered and resistance of soils to erosion decreases.

Table 4

Research data on chestnut soils of the Tsimlyanskiy Reservoir Basin

Profile No.	Soil group	Horizon and depth, cm	Indicators		
			Aggregation[a]	Dispersion[b]	Water-retaining capacity[c]
	Non-eroded				
26	Dark-chestnut (Stalingradskaya Oblast', Kalachevskiy rayon, Pyatiizbyanskaya station)	A 0—22	0,647	0,310	0,850
		B_1 27—37	0,552	0,260	0,926
		B_2 57—67	0,494	0,298	0,979
		C 105—115	—	0,347	0,988
51	Chestnut (Stalingradskaya Oblast', Kotel'nikovskiy rayon, Nagavskaya station)	A 5—15	0,637	0,357	0,897
		B_1 24—34	0,566	0,288	1,057
		B_2 48—58	0,554	0,328	1,152
		C 90—100	—	0,732	1,153
43	Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy rayon, Il'men'-Suvorovskiy farmstead)	A 0—14	0,408	0,328	0,949
		B_1 17—27	0,525	0,331	1,067
		B_2 37—47	0,516	0,444	1,264
		C 120—130	—	0,614	1,220
	Slightly eroded				
3	Dark-chestnut (Stalingradskaya Oblast', Kalachevskiy rayon, Pyatiizbyanskaya station)	A 0—10	0,644	0,327	0,985
		B_1 20—30	0,510	0,294	0,869
		B_2 36—46	0,459	0,324	0,804
		C 110—120	—	0,328	0,920
54	Chestnut (Stalingradskaya Oblast', Kotel'nikovskiy rayon, Nagavskaya station)	A 0—14	0,576	0,311	0,937
		B_1 20—30	0,503	0,297	0,908
		B_2 40—50	0,491	0,326	1,020
		C 90—100	—	0,332	1,038
8	Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy rayon, Il'men'-Suvorovskiy farmstead)	A 0—10	0,331	0,283	0,884
		B_1 18—28	0,322	0,301	0,912
		B_2 40—50	0,308	0,331	1,066
		C 86—96	—	0,615	1,123
	Severely eroded				
2	Dark-chestnut (Stalingradskaya Oblast', Kotel'nikovskiy rayon, Navavskaya station)	B_1 0—8	0,534	0,332	1,011
		B_2 10 - 20	0,442	0,337	1,007
		C 92—104	—	0,483	0,982
7	Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy rayon, Il'men'-Suvorovskiy farmstead)	B_1 0—6	0,315	0,351	1,129
		B_2 6 – 16	0,311	0,370	1,123
		C 55—65	—	0,317	1,145

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[a] Ratio of the quantity of particles <0. 05 mm in diameter without pre-treatment to quantity from pre-treatment analysis.

[b] Quantity of water-stable aggregates >0. 25 mm in diameter per 1g of soil.

[c] Amount of water retained in 1g finely dispersed soil.

Note: Comma represents decimal point.

Table 5

Average water used, in ml, for dispersing one aggregate 3-5mm in diameter, and the quantity of aggregates in chestnut soils of the Tsimlyanskiy Reservoir Basin expressed in % according to stability groups

Profile No.	Soil group	Horizon and depth, cm	Aver. water used, ml, for dispersing 1 aggregate	Very stable >200 ml		Stable 200-50 ml		Medium stable 50-10 ml		Unstable <10 ml	
				ml	%	ml	%	ml	%	ml	%
26	Dark-chestnut (Stalingradskaya Oblast', Kalachevskiy Rayon, Pyatiizbyanskaya station)	A 0—22 B_1 27—37	9,36 56,86	— 212,5	— 4	— 95,83	— 36	18,61 27,91	36 46	3,94 5,64	64 14
3	Slightly eroded dark-chestnut (See No. 26)	A 0—10 B_1 20—30	9,20 59,87	— —	— —	53,00 130,91	4 34	13,79 42,82	34 34	3,00 2,50	62 32
2	Severely eroded dark-chestnut (See No. 26)	B_1 0—8 B_2 8—22	5,33 30,85	— —	— —	— 86,20	— 20	39,50 30,66	6 38	3,17 4,67	96 42
51	Chestnut (Stalingradskaya Oblast', Kotel'nikovskiy Rayon) (Nagavskaya Station)	A 5—15 B_1 24—34	9,12 44,82	— —	— —	— 92,65	— 34	15,35 29,26	34 38	5,91 7,86	66 28
54		A 0—14 B_1 20—30	8,04 42,02	— —	— —	— 99,00	— 32	15,37 29,61	32 36	4,59 6,50	68 32
61	Slightly eroded Chestnut (See No. 51)	B_1 0—14 B_2 22—33	7,58 37,12	— —	— —	— 125,33	— 18	13,83 30,21	36 38	4,06 7,00	64 22
43	Light-chestnut (Stalingradskaya Oblast', Voroshilovskiy Rayon, Il'men'-Suvorovskiy farmstead)	A 0—14 B_1 17—27	6,29 39,20	— —	— —	— 105,43	— 30	41,20 20,59	10 34	2,41 1,86	90 36
8	Slightly eroded light-chestnut (See No. 43)	A 0—10 B_1 18—28	6,40 31,16	— —	— —	— 75,50	— 28	28,33 23,65	12 34	3,41 5,21	88 38
7	Severely eroded light-chestnut (See No. 43)	B_1 0—6 B_2 6—16	3,41 29,66	— —	- —	— 99,44	— 18	26,25 22,08	8 26	1,42 4,07	92 56

ote: Comma represents decimal point.

Table 6

Group composition of microaggregates in chestnut soils of the Tsimlyanskiy Reservoir Basin

Profile No.	Soil Group	% Particles			
		Group		Total of I and II groups	Part.Res >0.01 mm in diam.
		I	II		
26	Non-eroded dark-chestnut	48. 24	4. 91	53. 15	46. 85
3	Slightly eroded dark-chestnut	32. 87	11. 70	44. 57	55. 43
2	Severely eroded dark-chestnut	27. 60	14. 44	42. 04	57. 96
51	Non-eroded chestnut	47. 85	5. 99	53. 84	46. 16
54	Slightly eroded chestnut	39. 64	6. 15	45. 79	54. 21
61	Severely eroded chestnut	37. 78	6. 14	43. 92	56. 08
43	Non-eroded light-chestnut	42. 44	2. 95	45. 39	54. 61
8	Slightly eroded light-chestnut	37. 92	1. 35	39. 27	61. 73
7	Severely eroded light-chestnut	19. 51	18. 08	37. 59	62. 41

Table 7

Humus content in microaggregates and in the residue of chestnut soils of the Tsimlyanskiy Reservoir Basin

Profile No.	Soil group	% absolutely dry soil				
		In microaggregates			In residue	
		I	II	I and II	I	I and II
26	Non-eroded dark-chestnut	6.98	0.44	7.42	4.21	3.30
3	Slightly eroded dark-chestnut	6.19	0.76	6.95	3.07	2.67
2	Severely eroded dark-chestnut	5.18	0.82	6.00	3.06	2.35
51	Non-eroded chestnut	4.14	0.56	4.70	3.33	2.62
54	Slightly eroded	3.95	0.67	4.62	3.55	3.32
61	Severely eroded chestnut	1.52	2.11	3.63	3.13	2.86
43	Non-eroded light-chestnut	3.85	0.48	4.33	2.87	1.98
8	Slightly eroded light-chestnut	3.71	0.35	4.06	1.90	1.78
7	Severely eroded light-chestnut	3.16	0.32	3.48	1.17	1.82

In order to attribute to chestnut soils of the Tsimlyanskiy Reservoir Basin a strong resistance to erosion, and to create optimal water-air, thermal and nutritive relations for plants and microorganisms we constantly had to maintain the structure and to restore it, when lost.

Restoration of a water-stable structure in chestnut soils should adhere to the principles of proper soil cultivation, the application of a fertilizer system, the organization on the soils of slopes employing soil-protecting pasture-crop rotations by cultivation on them of beans and grasses, application of synthetic structure-forming materials, etc.

All the various methods used to restore the water-stable structure should be differentiated insofar as they apply to the agricultural soil regions of the Tsimlyanskiy Reservoir Basin.

CONCLUSIONS

1. The structure of chestnut soils in the Tsimlyanskiy Reservoir Basin is characterized by differences in water stability.

2. The water stability of the structure of chestnut soils is dependent upon the predominance of aggregates, formed from Group I microaggregates and from mineral particles through cementation by their free humic acids and humates.

3. Dark-chestnut soils, as compared with chestnut and light-chestnut soils, and non-eroded soils are compared with their eroded varieties possess a higher water stable aggregates and, consequently, a greater resistance to dispersion erosion.

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USE OF DEEP PLOWING FOR REGULATING THE WATER AND SALT REGIME IN SOILS OF THE ALEYSK IRRIGATION SYSTEM[1]

K. YA. FESKO AND E. V. STRUGALEVA, Altay Agricultural Institute

An important measure to improve the condition of irrigated soils is deep tillage. It facilitates leaching salts from the upper soil horizons by better and rapid absorption of rainfall and irrigation water. Deep tillage increases the total porosity and water holding capacity of the soil and destroys the capillary system of the upper horizons. It thereby makes the movement of salts with capillary moisture difficult. This is important for irrigation systems having high water tables, especially for the Aleysk Irrigation System in the Altay Kray, where the mineralized ground waters on a large portion of the irrigated area are now at a depth of from 2. 5-3. 0 m or more from the soil surface during the growing period and supply the upper soil layer (0. 5 m).

On July 12, 1951 on the Rubtsov sugar beet state farm, we set up a preliminary experimental planting of spring wheat on 3 ha of deeply tilled fallow ground. Owing to the lack of equipment necessary for deep plowing, a road ripper was used with dull chisels set 50 cm apart. The soil was tilled to an average depth of 45 cm across the ordinary cultivation, with the aid of a S-80 tractor.

The soil of the plowed plot varied widely from a weakly saline southern structureless chernozem on coarse and medium silty clay loams to solonchak spots. As to salinity, the soils were classified as moderate and highly mineralized with a solid residue of 0. 69%-0. 93%. Moderately mineralized ground waters of the sulfate type were 2. 50 m from the surface. After plowing, the plot was harrowed, cultivated, etc. During the winter a significant amount of snow was retained, which together with the early spring precipitation, made the soil very moist both in the experimental and the control plots.

Our equipment did not break up the subsoil well because of the distance between the chisels. While digging in 1951 we observed traces of the chisels between which there were untilled spots with separate cracks. In the spring of 1952 there were no visible traces of the equipment. During the ten months of the autumn and winter of 1951-1952, the soil settled and became compacted. Observations of moisture showed that even where the soil was far from being completely deep tilled, the moisture was higher in the experimental plot than in the control from the fall of 1951 and throughout the summer of 1952 (Table 1).

The greater accumulation of moisture in soil as compared to the control showed up mainly in the uppermost half-meter, which was deep tilled. The increase in moisture in this layer was from 7. 0-27. 0 mm, the maximum accumulation being in the second year after tillage. The increased amount of moisture in the second half-meter is evidently due to lower moisture loss by evaporation and by better penetration of rainfall through the deep tilled upper layer. Irrigation at the rate of 80 mm between June 6 and July 5, 1952 increased the absolute amount of moisture in the experimental plot as well as in the control. However, with deep tillage during this period there was a greater accumulation of moisture from irrigation and rainfall.

In August 1954, we set up an experiment in the same state farm, on a strongly saline 3. 5 ha plot alongside highly thinned out perennial grasses, using different variations of deep plowing in four replications. The variations of the experiment were as follows: plowing with an ordinary plow and coulter to a depth of 25-30 cm, with a P-3-30 plow having a subsoiler to a depth of 40-45 cm, and with the same plow and subsoiler (moldboard removed)

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[1] The field experiments were carried out by the authors between 1951 and 1955 on the Aleysk Irrigation System jointly with G. S. Goppe and with the participation of the assistant in the Soil Science department of the V. P. Zhukov Altai Agricultural Institute. This work was under the general direction of Professor N. V. Orlovskiy.

Table 1

Amounts of moisture on deep tillage

Date sample taken	Depth, cm	Moisture content, (mm)		Increase in moisture compared with the control, mm	Precipitation and irrigation for the observation period, mm
		Tillage	Control		
July 12, 1951	0–50	124	--	--	
	50–100	130	--	--	
Sept. 12, 1951	0–50	122	115	7	15.0
	50–100	144	129	15	
May 17, 1952	0–50	174	162	12	127.0
	50–100	176	174	2	
June 30, 1952	0–50	116	102	14	20.0
	50–100	134	132	2	
July 5, 1952	0–50	154	127	27	Precip. 17.0 mm and irr. 80 mm
	50–100	140	130	10	

Table 2

Bulk density up to and after plowing

Determination date	Treatments	Depth, cm					
		0–10	10–20	20–30	30–40	40–50	50–60
July 27, 1954	Before plowing	1.32	1.32	1.24	--	1.21	1.26
	After plowing:						
Sept. 11, 1954	Ordinary plowing	1.04	1.02	1.05	1.25	1.22	--
Sept. 10, 1954		0.97	0.98	0.95	0.93	0.97	1.12
	Spring						
May 11, 1955	Ordinary plowing	1.04	1.28	1.38	1.27	1.35	--
	Deep plowing with soil turned over	1.15	1.26	1.32	1.27	1.31	1.26
	Deep plowing without moldboard	1.04	1.33	1.35	1.26	1.30	1.33
	After Irrigation						
July 15, 1955	Ordinary plowing	1.40	1.32	1.34	1.23	1.27	--
	Deep plowing without moldboard	1.34	1.39	1.30	1.26	1.32	1.33

hout turning over the soil to a depth of 45- cm. The deep plowing was done with a DT- tractor. Before and after plowing the bulk nsity was determined in four replicates able 2).

The depth of deep plowing was confirmed both a sketch of the profile by sections and by the nge in bulk density before and after plowing. th ordinary plowing the bulk density changed about the 30 cm depth and with deep plowing the 50 cm depth. By the spring of 1955 bstantial self-compaction had taken place l the bulk density differed little from one atment to the other. It was nearly equal to t before plowing, and after the first irrigation (June 2) it was completely evened out. Similar self-compaction also occurred after the winter of 1952 when diggings were made on the plot loosened with a ripper in 1951. The soil in the Aleysk Irrigation System became quite compacted because of the autumn-winter-spring rains. Since this process is increased during irrigation, maintaining the effectiveness of deep tillage evidently requires more frequent deep plowing on irrigated land than on non-irrigated land.

Depth of plowing also affected soil freezing and thickness of the frozen layer. With deep plowing the frozen soil layer was not as thick; thawing was more rapid and penetrated to a greater depth, an average of 5 cm. However, soil moisture had a still greater effect on the depth to which freezing occurred. The greater the amount of moisture, the shallower the depth of freezing. At the same time, very moist frozen soil thawed out more slowly in the spring.

Systematic observations of soil moisture for two years (1954-1955) showed that after plowing in 1954 moisture in all variations of the experiment decreased sharply in the mellowed layer of the soil, whereas below this layer it remained almost unchanged up to the fall of 1954. This was quite evident in figures 1 and 2. These changes, computed as the difference between the amounts of moisture by layers and periods, are expressed by the figures shown in Table 3.

It follows from Table 3 that for 20 days after plowing in August there was a decrease of 37. 0-47. 0 mm of moisture in the first-meter layer in all the treatments over the amount before plowing (although during this time the precipitation totalled about 40 mm, of which 5-8 mm was in the form of a light rain). Therefore, the main loss of moisture (some 70%-80%) came from the upper half-meter layer. From June 25-September 26, 1954 a small increase in moisture (about 16. 0 mm) was observed to be uniform throughout the whole top meter layer on the plot with ordinary plowing, whereas in both treatments with deep plowing the greatest decrease in moisture took place in this layer (with 62 mm of precipitation for that period) but it was not as sharp as in August.

The increase in moisture after ordinary plowing evidently was due chiefly to capillary rise from the ground waters, which were then 2. 6 m below the surface. After deep plowing (with and without turning over the soil) this phenomenon did not occur, but the evaporation was more intense here than after ordinary plowing because of increased porosity and with free access of air through the large cracks and pores formed.

From October 1954-May 1955, the moisture increased on all plots from the autumn-winter-spring precipitation. On the plot with ordinary plowing, the moisture was about 38. 0 mm while on the deeply plowed plots it was about 75-79 mm, i. e. almost double. Here the advantage of deep plowing with respect to moisture accumulation was evident, mainly in the loosened layer in spite of self-compaction. It would have been much greater if the snow had been retained. During May the amount of moisture decreased on all plots to about the same value (from 19-37 mm). Then, owing to irrigation (June 3) at the rate of 60 mm, the moisture in the top meter layer rose from 30-56 mm. Moreover, the increase in moisture after irrigation in the plot with deep plowing appeared to be uniform throughout the top meter layer, whereas in the plot with ordinary plowing generally only the top half-meter was soaked. Deeper soaking would have required longer irrigation. After the second irrigation (June 21) at the rate of 800 cu m/ha this distribution of moisture throughout the profile was not observed. Further observations until the fall of 1955 and during 1956 showed no essential differences in moisture conditions. The reason is more uniform compaction of the soil in all the plowing treatments.

Deep plowing with a subsoiler on irrigated land, especially without turning over the soil, also had a positive effect on desalinizing the soil by making easier leaching of the salts from the upper horizons possible and by decreasing their ability to rise with capillary moisture from the deeper horizons. Systematic observations of the salt regime in connection with differences in methods of cultivation were made from 1954-1956 (Table 4) on one of the plots used for the four replications of the soil moisture experiment.

The plots were laid out 25 m from each other When irrigation was applied at the rate of 800 cu m/ha an endeavor was made to distribute the water uniformly over the plots. Soil sample were taken from five places with a spade from the 0-5 and 5-20 cm depths and from three places with a soil borer from the 20-40, 50-70 and 80-100 cm depths. The salt composition was determined from water extracts (soil to water ratio, 1:5).

Significant variability was observed in soil salinity throughout the experimental area and on the plots. Therefore, it was not always possible to obtain a single uniform average sample. Certain discrepancies in the curves of changes in salt regime and moisture at separate times of observation can obviously be attributed to flooding conditions on the plots and their individual differences.

At the time the experiment was set up (June 31, 1954) all three plots were classified as highly salinized southern chernozems (chloride-sulfate type, see Table 5).

Observations of the salinization over three years showed a general drop in the degree of salinity with various cultivation methods throughout the entire top meter layer of the soil with sharp fluctuations varying with irrigation and precipitation. Regular irrigation at the rate of 700-800 cu m/ha, fall-winter precipitation, and partial utilization of the salts by the sugar beets helped to lower the general salt content. In the first part of the experiment the most intensive desalinization after irrigation occurred when plowing was done without turning over the soil. By the spring of 1956 (April 24) the formerly high saline soil was observed to have become weakly

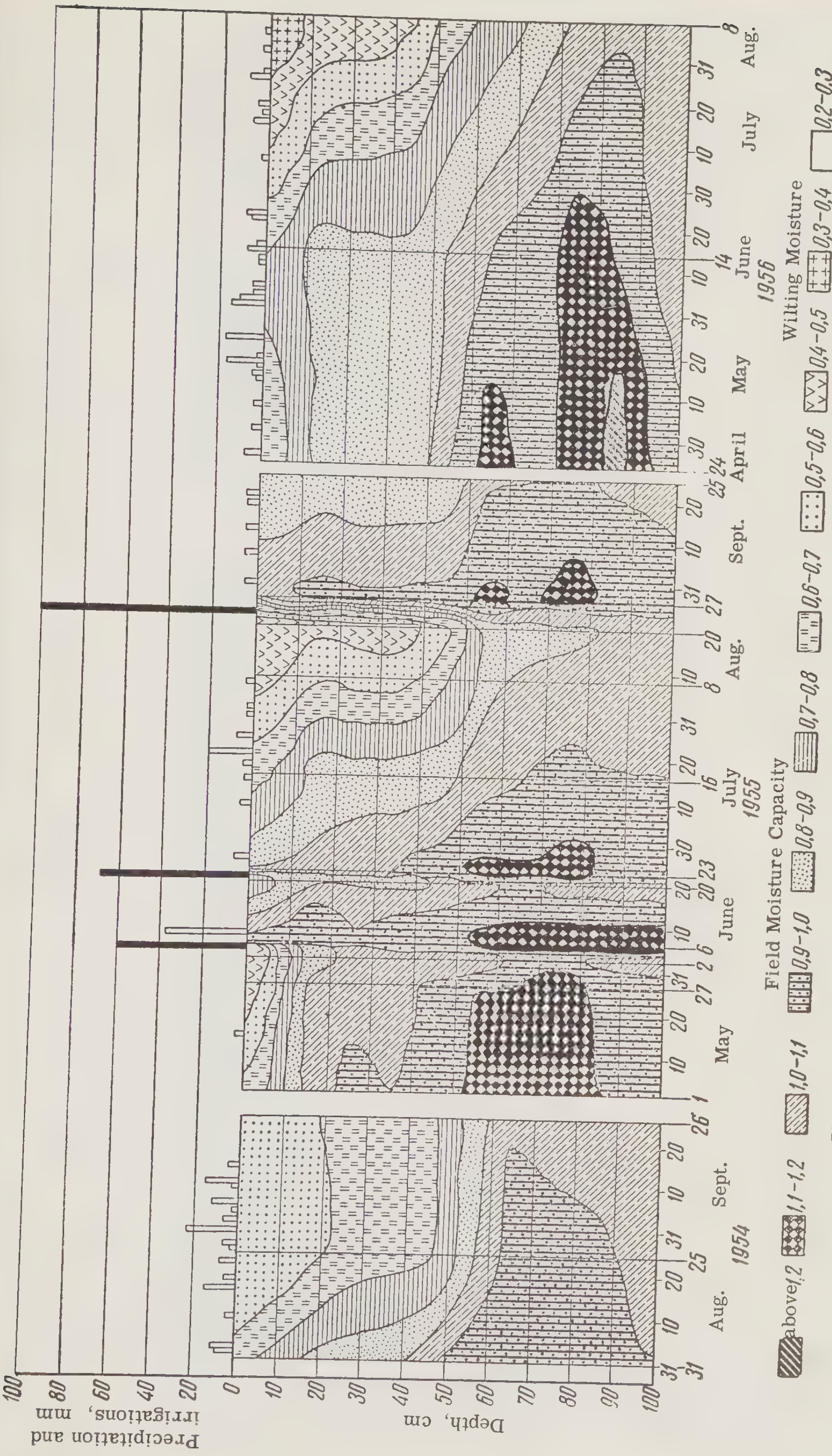

Fig. 1. - Dynamics of soil moisture after deep plowing without turning over the soil.

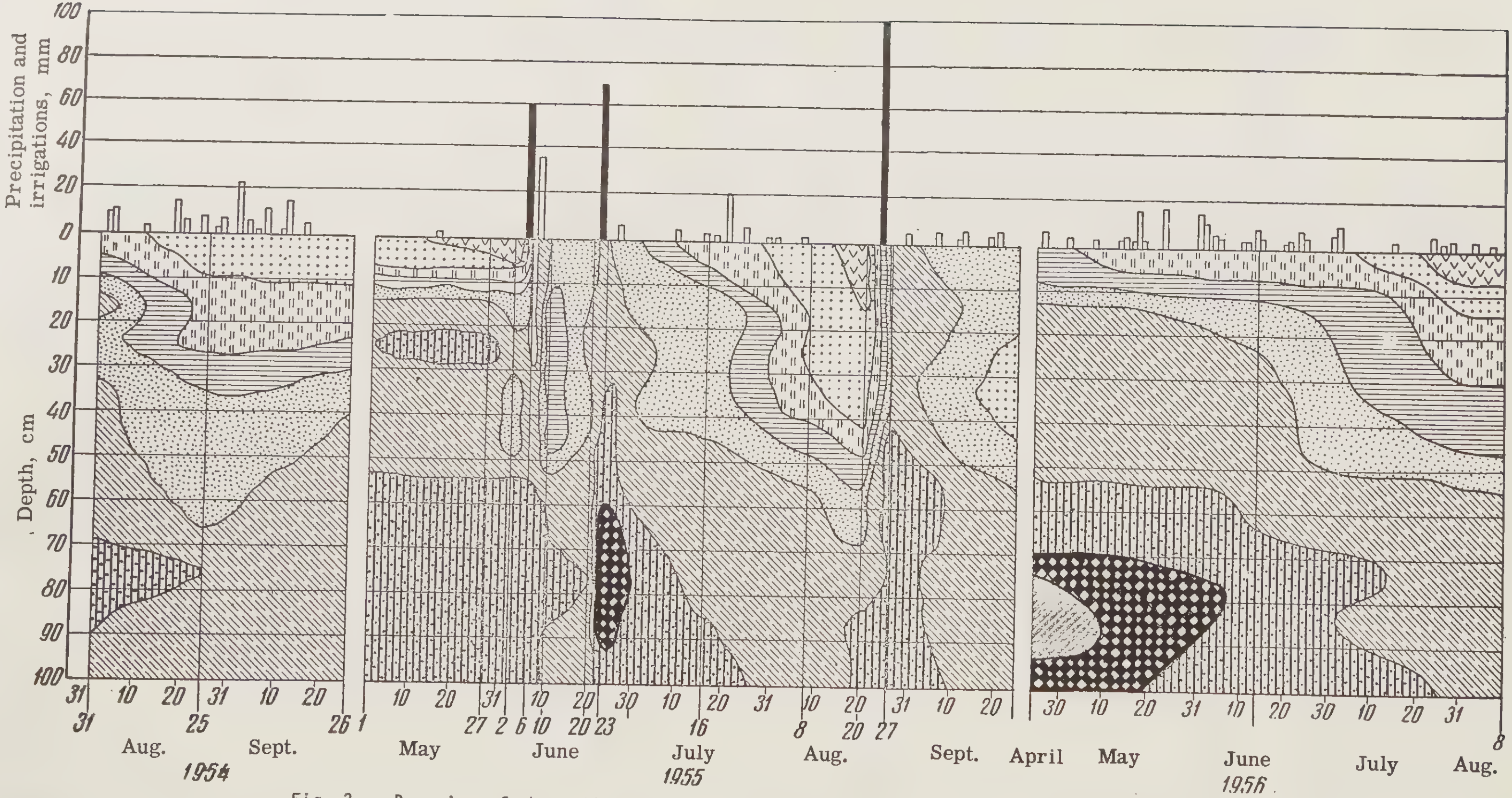

Fig. 2. - Dynamics of the soil moisture after ordinary plowing (For Legend see Fig. 1).

Table 3

Change in amounts of water in the soil with respect to manner of plowing (sugar beets)

Treatment	Depth, cm	Amount of moisture after plowing mm	Dates soil samples taken											
			1954			1955								
			8/7-8/25	8/25-9/26	9/26-5/1	5/1-6/2	6/2-6/6	6/6-6/20	6/20-6/23	6/23-7/16	7/16-8/8	8/8-8/20	8/20-8/27	8/27-9/25
Ordinary plowing	0—30	85	—23	+2	+21	—7	+25	—10	+8	—15	—26	—11	+50	—15
	0—50	145	—29	+8	+30	—11	+31	—14	+18	—26	—39	—18	+76	—29
	0—100	229	—41	+16	+38	—19	+29	—16	+38	—43	—47	—21	+95	—52
Plowing with subsoiling	0—30	92	—24	—5	+22	—12	+23	—10	+16	—	—	—14	+57	—24
	0—50	151	—37	—8	+47	—16	+27	—23	+27	—	—	—21	+83	—35
	0—100	308	—37	—17	+76	—28	+45	—47	+43	—	—	—31	+116	—55
Plowing without turning over the soil	0—30	82	—24	+3	+30	—14	+26	—12	+7	—15	—26	—11	+60	—19
	0—50	142	—42	+3	+53	—20	+35	—22	+16	—29	—39	—19	+95	—34
	0—100	299	—47	—6	+79	—37	+56	—45	+36	—46	—49	—31	+133	—52
Note:					From fall and winter precipitation		Irr. 60 mm		Irr. 80 mm				Irr. 80 mm	

Table 4

Salt Balance, metric tons/hectare

Treatment	Depth, cm	Dry residue, %		Date				Decrease from 1954-1956	
		1954	1956	July 31 1954	June 8 1955	Mar. 20 1955	April 24 1956	metric tons/ha	%
Ordinary plowing	0—20	0,70	0,53	18,8	19,6	13,9	14,4	4,4	23,4
	0—50	0,78	0,61	51,0	50,0	41,2	40,8	10,2	20,0
	0—100	0,75	0,61	101,8	108,4	83,3	84,2	17,6	17,3
Plowing with subsoiling	0—20	0,81	0,47	23,5	23,4	13,3	12,7	10,3	44,0
	0—50	0,82	0,57	55,9	59,9	40,9	37,9	18,0	32,3
	0—100	0,68	0,59	97,9	111,6	90,9	82,1	15,8	17,0
Plowing without turning over the soil	0—20	0,77	0,38	20,4	11,0	12,6	11,2	9,2	44,8
	0—50	0,97	0,39	62,9	35,8	30,8	25,9	37,1	59,1
	0—100	0,73	0,43	97,7	75,7	61,2	60,2	37,7	38,6

Note: Results of the analyses are the average of weight data for the entire depth.

Note: Comma represents decimal point.

Table 5

Ionic content, metric tons/hectare

Treatment	Depth, cm	HCO_3^-		Cl^-		$SO_4^=$		Ca^{++}		Mg^{++}		Na^+	
		'54	'56	'54	'56	'54	'56	'54	'56	'54	'56	'54	'56
Ordinary plowing	0—20	0,5	0,8	1,58	0,8	9,3	9,2	1,6	2,2	0,3	0,3	3,4	2,4
	0—50	1,3	2,0	3,9	2,0	26,7	28,9	2,6	5,3	0,7	1,3	8,5	6,7
	0—100	3,5	4,2	8,9	6,3	50,5	48,4	7,6	8,2	2,1	2,8	18,5	16,0
With subsoiling and turning over the soil	0—20	0,8	0,5	3,2	1,6	10,3	5,4	2,4	1,6	0,5	0,3	3,7	1,4
	0—50	2,0	1,3	7,2	3,3	25,4	18,6	5,9	4,7	1,3	0,7	9,8	3,3
	0—100	4,1	3,5	11,5	5,5	46,2	45,3	9,5	6,1	2,7	2,0	14,4	11,3
With subsoiling without turning over the soil	0—20	0,8	0,5	0,5	0,5	11,9	3,8	2,9	0,8	0,3	0,3	2,6	1,1
	0—50	2,0	1,3	1,9	0,7	37,6	12,6	6,5	2,7	1,3	0,7	9,8	2,7
	0—100	4,1	4,2	4,1	2,1	57,0	32,9	8,7	5,5	2,0	2,1	16,9	9,1

Note: Comma represents decimal point.

saline after plowing without turning over the soil.

At the same time, however, highly saline plots became moderately saline after ordinary plowing and subsoiling.

The data on content of individual ions in metric tons/ha according to type of cultivation for the initial and final periods (July 31, 1954 and April 24, 1956) are presented in Table 5.

With deep plowing desalinization primarily involved the Cl, SO_4, Na and Ca ions. With ordinary plowing these ions migrated to the second half-meter layer from the surface. After cultivation without turning over the soil most of these ions were leached out of the top meter layer.

The salt concentration of the soil solution in the 0-20 cm layer (Table 6), calculated from the water extract data and the gravimetric soil moisture[2] data obtained May 1, 1955 and June

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[2] $\frac{\text{Dry residue per 100 g soil x 100}}{\text{soil moisture}}$

Table 6

Salt concentration of the soil solution

Treatment	Depth, cm	Dry Residue, %	Meq. in 100 g solution					
			HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+
July 31, 1954								
Ordinary plowing	0—20	3,3	1,7	10,0	45,5	23,2	7,2	26,9
	0—50	3,5	1,7	7,9	39,0	17,1	5,6	24,9
	0—100	3,4	1,9	8,1	37,7	14,5	7,5	25,4
With subsoiling	0—20	3,8	1,4	14,4	35,7	19,6	4,6	28,0
	0—50	3,6	1,7	12,8	36,9	18,7	4,6	28,3
	0—100	3,1	2,0	9,8	32,5	15,0	4,5	24,8
Without turning over the soil	0—20	4,5	2,1	3,1	46,4	25,8	4,3	21,4
	0—50	4,8	2,3	4,8	55,5	25,0	8,2	29,2
	0—100	3,5	2,2	4,7	39,9	15,8	6,9	24,5
April 24, 1956								
Ordinary plowing	0—20	2,3	2,3	3,4	30,5	14,5	3,8	17,8
	0—50	2,7	2,0	3,2	35,1	17,1	5,2	17,8
	0—100	2,7	2,0	5,1	32,5	12,5	3,0	21.4
With subsoiling	0—20	2,1	2,1	7,1	19,9	14,6	3,2	11,3
	0—50	2,5	2,1	6,1	26,0	15,8	3,9	14,5
	0—100	2,5	2,1	5,0	28,0	12,7	5,4	17,0
Without turning over the soil	0—20	1,7	1,7	2,5	19,6	11,9	2,4	9,3
	0—50	1,8	1,8	1,9	21,8	12,6	3,1	9,6
	0—100	1,9	2,1	2,4	22,8	10,8	3,6	12,7

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ote: Comma represents decimal point.

1955, was high throughout the entire growing riod (it was lower in the treatment involving wing and turning over the soil). The salt ncentrations calculated for ordinary plowing, bsoiling and turning over the soils and plow- ; without turning over the soil had the follow- ; values, respectively, for the two periods entioned: 4. 4% and 5. 1%; 3. 6% and 5. 2%; 1% and 4. 1%. In the same layer (10-20 cm) soil solution concentrations went from near ic to completely tolerable at the end of the periment and according to the type of cul- ation were 2. 3%, 2. 1% and 1. 7% respective- while in the top meter layer they were 7%, 2. 5% and 1. 9% respectively.

The ionic composition of the soil solu- ns on the plots was not quite uniform, pecially with respect to chlorides (Table There were more chlorides on the bsoiled plots. At the start of the experi- nt (July 31, 1954) the chloride concen- tions in the soil solution were 7. 9%, 8% and 4. 8% and at the end (April 24, 56) they were 3. 2%, 6. 1% and 1. 9%, spectively. Although the general chloride ncentration decreased 2. 0- 2. 5 times, ratios between the variations remained out the same.

The positive effect of deep plowing was reflected in the sugar beet yield and especially in the seed yield (in a production experiment without replication). Because of the highly saline plot, the grass growing with the sugar beets was patchy and in some poorly irrigated places there was none at all. The latter were not included in the area taken into account.

In all the treatments during the dry year of 1955 the sugar beets were irrigated three times with 600-800 cu m/ha of water each time. The average yield from four replications of 0. 3 ha each (the total calculated area for each treatment was about 1 ha) was as follows:

	Beet (cntr/ha)	Seeds (cntr/ha)
Deep plowing without turning over the soil	294. 3	16. 9
Deep plowing and turning over the soil	286. 7	--
Ordinary plowing	280. 9	13. 3

Thus, under unfavorable conditions (substantial soil salinity and drought) the increase in beet yield on deeply plowed plots ranged from

15-24 cntr/ha, while the seed yield amounted to 3.6 cntr/ha. Under these conditions deep plowing had a more positive effect on the increase in the seed yield than did the sugar beet roots.

CONCLUSIONS

1) Southern chernozems on coarse and moderately silty clay loams in the Aleysk Irrigation System became quickly compacted after rainfall and especially after irrigation, rapidly losing their porosity brought about by deep tillage. For that reason deep plowing must be done more often when soils are irrigated.

2) Deep plowing with and without turning over the soil creates better conditions for storing moisture from winter and summer rains and insures better distribution of irrigation water throughout the soil profile in the first year. Drying of the soil to the tilled depth is observed in a dry period after plowing.

3) Deep plowing with subsoiling, especially plowing without turning over the soil, has a positive effect on the salt regime of the soil, making more intensive desalinization possible after precipitation and irrigation than with ordinary plowing. Concentration of the soil solution in the 0-20 cm layer, which is almost toxic, is thereby reduced to a permissible level. With ordinary plowing the concentration of soil solution is 2.3%, with subsoiling 2.1%, and without turning over the soil, 1.7%. With all forms of plowing the degree of salinity was reduced from strongly saline to moderate.

4) In the first year deep plowing of irrigated lands creates more favorable conditions for plant growth and helps to raise the yield of sugar beet, especially of seeds.

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EASONAL FREEZING OF BARABA BOG SOILS NDER CULTIVATION

. R. VERNER, Omsk

Srebryan'skaya (10) made the first observa-
ons of freezing and thawing of the bog soils
the central part of Baraba. During her three-
ar study, the peat-bog soil of the virgin, low-
nd bog with a sedge-beach grass-fescue as-
ciation, froze to a depth of 0. 5 m; the latest
riod of complete thawing occurred during the
st 10 days of May.

Further observations of drained and culti-
ted bogs showed that winter freezing of
ltivated bog soil is much deeper than that
virgin bog soil, and that the thawing period is
nger. This prompted more detailed studies
the seasonal freezing of these soils. This
port gives data on the seasonal freezing
fect on soil temperature during the growing
ason, and the nitrogen mineralization of
at and soil aeration in a drained and cultivated
g.

Seasonal Freezing and Soil Temperature

According to the Ubinskaya Experimental
lioration Station's meadow crop rotation
stem for cultivating the Baraba lowland bogs,
ere the peat deposit is at least 0. 5 m thick,
first cultivation of the soil consists of plow-
with a shrub-bog plow and of separating the
ers with a peat shredder. After one or two
ars of cultivating annual crops, the bog is
ned into grassland. Table 1 shows the
mparative data for a number of years describ-
the freezing effect on cultivated and virgin
gs. The depths of the winter freeze and thaw
re determined either by digging holes or by
Danilin method of measuring frozen ground.

Observations show that the drained and cul-
ated bog freezes to approximately a depth of
-100 cm and thawing continues until August.
a virgin bog, the thickness of the frozen
l layer by the end of winter is about 50 cm
complete thawing lasts until the end of May.
eater freezing of cultivated bogs in other re-
ns is indicated in the literature (7).

A study of the individual factors responsible for the difference between the freezing of virgin and cultivated bog soils was not part of our study. Other conditions being equal, for a cultivated bog the amount and time of snow fall are decisive. We previously established the major role played by the snow cover in soil freezing for the tilled fields of Baraba.

Consequently, we must assume that this factor is the basis for the difference in freezing of virgin and cultivated bogs. According to the many years of observations at the Ubinskaya Experimental-Melioration Station, snow accumulations on a virgin bog begin early and reach a depth of 50-60 cm; this is associated with the presence of dry grassland composed of sedge, reeds, fescue and other vegetation. After the bogs are cultivated, the snow accumulation is the same as on an open steppe.

We used snow as a thermal factor while conducting our research on changing the degree of soil freezing. For this purpose, in similar fields of the cultivated bog, certain plots remained under a natural snow accumulation, while in others, the snow was restricted by various types of barriers from the very first falls. Suitable observations were made as to the different depths of soil freezing in these field experiments. Over a period of a number of years, daily readings were made from a Savvinov thermometer which was installed after the flood stage on the experimental plots. The results over the years were the same. Therefore, Table 2 shows the results for one year only (1953).

Table 2 shows that the mean temperature of the plowed layer with slight soil freezing is two or more degrees higher than on the deeply frozen plot. This difference reaches a characteristic maximum in the hottest period (July and the first 10 days of August). As will be seen from the data on the ground-water temperature (Table 5), this difference in the soil temperature is retained depending on freezing in the soil's

Table 1

Depth of winter freezing and period of complete thawing in a reed-sedge bog in the virgin state and after cultivation in 1948-1949

Characteristics of the plot	1949-1950		1950-1951		1951-1952	
	Depth of freezing, cm	Period of complete thawing	Depth of freezing, cm	Period of complete thawing	Depth of freezing, cm	Period of complete thawing
Virgin drained bog	35—40	May 17	50—55	May 15	45—50	May 23
Cultivated bog in the first year of cultivation; plowed or winter-rye	77—80	Aug 17	75—82	Aug 12	70—72	Aug 5
Cultivated bog; perennial grasses of various ages	—	—	—	—	80—90	Aug 19

Characteristics of the plot	1952-1953		1953-1954	
	Depth of freezings cm	Period of complete thawing	Depth of freezings cm	Period of complete thawing
Virgin drained bog	50—52	May 27	45—50	May 22
Cultivated bog in first year of cultivation; plowed or winter-rye	81—83	Aug. 2	82—100	Aug. 24
Cultivated bog; perennial grasses of various ages	72—75	July 27	68—73	Aug. 30

Table 2

Temperature of plowed layer in growing season (1953) relative to depth of winter soil freezing (numerator-during light soil freezing; denominator-during deep soil freezing)

Depth, cm	Month										Mean temperature for the season
	June			July			August			September	
	Decade										
	I	II	III	I	II	III	I	II	III	I	
5	11,6 10,7	10,5 9,1	12,3 10,6	16,7 14,1	19,9 14,9	20,1 17,3	19,4 15,4	16,0 13,0	11,2 10,3	12,5 11,6	15,0 12,7
10	10,4 9,2	10,4 8,7	11,6 9,0	15,2 12,5	17,6 14,6	18,6 15,8	19,2 15,3	14,2 13,8	11,8 11,8	12,1 12,1	14,1 12,3
15	9,4 8,3	10,5 8,3	10,9 8,3	15,2 11,8	17,2 14,1	19,8 15,3	17,6 14,8	15,5 14,4	13,3 12,5	13,0 12,5	14,2 12,0
20	7,9 5,9	9,6 6,3	10,8 6,3	14,3 9,7	16,5 11,5	18,7 14,5	17,5 14,3	15,0 14,5	13,8 12,6	14,2 12,6	13,8 10,8

Note: Comma represents decimal point.

per layers. All this indicates that winter ezing causes severe changes in the temper- re conditions of soil, and must be taken into sideration when evaluating the seasonal ezing of cultivated bogs.

Seasonal Freezing and Mineralization of Nitrogen in Peat

Studies by the Ubinskaya Experimental- lioration Station on the effectiveness of fer- zer on the Baraba cultivated bogs (9) indi- ed that despite large supplies of nitrogen in t, nitrogen fertilizer greatly increases the ld of cultivated crops. This is due to slow eralization of nitrogen in peat during its tivation. Periodic determination of nitrates he plowed layer showed that even in fallow as, nitrates are not to be found in notice- e quantities until the end of summer and, en crops are planted, they are absent during period when the crops need them most.

The data given in Table 3 are the basis for assumption that the slight decomposition eat, particularly the accumulation of ni- tes, is due to the influence of seasonal ezing on soil temperature during the growing son. Table 3 shows the data for two years the accumulation of nitrates in the plowed er of a cultivated bog having various degrees soil freezing caused by snow retention.

Studies were conducted on the following fall wed plots:

Plot No. 1, without snow retention. Snow osit, 18-20 cm. Soil freezing to 100 cm, complete thawing by July 25-28. In the spring, the plot was sown with barley. Samples were taken from the fallow area.

Plot No. 2, with snow retention. Snow deposit, 60-70 cm. Soil freezing to 35-40 cm, complete thawing in the first half of May. Other factors are the same as for the preceeding plot.

Plot No. 3, without snow retention. Snow deposit, 20-25 cm. Soil freezing to 78 cm; complete thawing by mid-July. In the spring the plot was sown with spring wheat. Samples were taken from the wheat-fields.

Plot No. 4, with snow retention. Snow deposit, 90-100 cm. Soil freezing to 30-40 cm; complete thawing early in May. Other factors are the same as for the preceeding plot.

Table 3 shows that severe freezing of both cultivated and fallow soils impedes the accumulation of nitrates several times more than does mildly frozen soil. Tsyplenkin shows that the slow accumulation of nitrates in soils for the central regions of Yakutiya is due to permafrost.

Data will be examined which indicate the poor aeration in bog soils when they are deeply frozen. Without exception, in addition to the temperature factor, it is likely that aeration plays a significant role in the accumulation of nitrates in the soils investigated, for aeration is known to influence greatly nitrification. This problem was not studied extensively in our work. We can only confirm that seasonal freezing seriously hinders the mineralization of nitrogen in peat.

Table 3

Accumulation of nitrates in peat relative to winter soil freezing (mg of NO_3/kg of dry soil)

Data by A. I. Brysova and Ye. A. Gordeyeva

Plot No.	Year	Depth, cm	June	July	August	September
1	1950	0—20	17,3	32,82	48,09	63,28
		20—40	7,75	23,89	38,51	39,23
2		0—20	106,90	84,91	127,80	82,74
		20—40	53,16	57,63	45,00	27,28
3	1951	0—10	Trace		15,61	43,57
		10—20	"		16,12	14,16
4		0—10	33,24	20,42	32,60	57,61
		10—20	16,93	22,45	20,35	35,32

Note: Comma represents decimal point.

Seasonal Freezing and Aeration of Bogs

In our previous work (4), we established that there is a considerable improvement in the aeration of bog soils by draining and especially by cultivation, as shown by the increased content of dissolved oxygen in the ground water (vadose) and by decreased hydrogen sulfide content. Further observations showed that for aeration of bog soils already under cultivation, the significant factor is seasonal freezing, and this phenomenon was studied in more detail.

As indicated, owing to deep winter freezing, a layer of frozen peat can be found in spring or summer at some depth in the soil. Frozen peat is practically impervious to water (5, 6), and thawing occurs only on the surface. As a result, throughout the entire thawing period, depending on the amount of winter and summer precipitation and on the depth to which thawing occurs, surface waters stand on the soil for a certain time, but when they disappear, sub-permafrost water is discovered by drilling.

We studied the content of dissolved oxygen and hydrogen sulfide in these bog waters for a number of years and under different crops. Table 4 gives the data on the content of dissolved oxygen and hydrogen sulfide in the stagnant surface waters and sub-permafrost waters which were collected in the winter-rye field in 1953. In order to analyze the surface water, samples were taken by dipping flasks (of the required size) directly into the water on the surface of the soil; and sub-permafrost water was obtained by digging holes on trenches to the depth of the thawed soil. Samples were taken by the same type flasks after a constant water level was established in the hole or trench. Oxygen was determined by the Winkler method, and hydrogen sulfide by the iodometric method (8).

These data, together with the observations of other years, show that surface waters, even when they are stagnant, are always rich in dissolved oxygen and do not contain hydrogen sulfide. This is explained by the high content of oxygen in melt water and rain water, from which stagnant water is formed, and by the infestation and vegetation of higher plants and algae. The phenomenon of oxygen supersaturation of ponded waters, caused by the vegetation of green plants in them, has been known for a long time (1). As our data show, this is also possible in stagnant surface waters. The situation is different with sub-permafrost water. As the numbers in the Table indicate, there is little or no dissolved oxygen in them; hydrogen sulfide is found.

All these data show that owing to the frozen state, aeration is spontaneously created in the upper thawed layer of the bog soils. It is determined by the quantity of atmospheric precipitation, the velocity of its run-off and by the intensity of evaporation, but is not related to the depth of the standing ground water (vadose).

We now examine data on the aeration of ground water during the soil thawing period (Table 5).

Determinations were made on a plot which had been cultivated for two years and on which oats were sown in the spring after fall plowing. In one case, snow had been retained from the first snowfalls and by the end of winter this layer had reached 100 cm. Freezing of soil occurred only in spots to a depth of about 45 cm; complete thawing occurred by the end of May. In another case, the snow was not retained and by the end of winter its layer was 30 cm. The soil froze solidly to a depth of 82 cm; complete thawing occurred by the end of July. Test samples were taken from permanent holes which were made at the end of winter (before the beginning of snow thawing). These holes were pumped out each time on the day before taking the samples. Some

Table 4

Content of dissolved oxygen and hydrogen sulfide in surface and sub-permafrost waters in a cultivated bog (Data from Ye. A. Gordeyeva)

Sample	Indicators	Time of sampling					
		April 24	April 28	May 6	May 7	May 8	May 9
Surface water standing after passage of flood	O_2 (% of saturation)	89.3	115.9	110	114	Not det'd.	
	H_2S per mg/l	0	0	0	0		
	Temperature, °C	12.6	11.8	12.5	17.6		
Sub-permafrost water Samples from trench dug to the frozen layer (to a depth of 30-35 cm)	O_2 (% of saturation)	1.40	0.81	0.96	0	0	0
	H_2S per mg/l	0.37	0.24	0.46	0.93	1.32	1.19
	Temperature, °C	4.4	2.4	3.6	3.8	5.2	--

Table 5

Aeration of ground water (vadose) relative to depth of soil freezing
(Data from Ye. A. Gordeyeva)

ariant	Indicators	Time of sampling									
		April 1	May 15	May 26	June 1	June 8	July 11	July 15	July 22	Aug. 12	Sept. 15
n snow	O_2 (% of saturation)	0.65	38.90	20.80	53.70	25.02	49.09	12.5	6.25	5.70	5.70
tention	H_2S per mg/l	3.16	Trace	0	Trace	0	0	0	0	0.17	0
	Level of ground water, cm	195	40	74	79	82	86	90	98	107	110
	Temperature of ground water, ^{0}C	3.4	2.6	2.6	2.4	2.9	5.0	4.0	4.2	4.6	6.0
hout	O_2 (% of saturation)	0	21.35	10.30	19.0	12.31	23.42	14.30	5.64	4.50	3.90
ow re-	H_2S per mg/l	3.72	Trace	0.34	0.37	0	0	0.36	0	0.18	0.55
ntion	Level of ground water, cm	195	108	110	116	115	88	93	99	107	115
	Temperature of ground water, ^{0}C	3.4	2.0	2.2	2.4	2.4	3.0	2.6	2.6	2.9	4.0

E: Thawing of snow began from the second half of April.

es were made in slightly frozen soil, others
leeply frozen soils.

The data of Table 5 show that in the spring-
mmer period, the oxygen and hydrogen sul-
content in the ground water is different
varies with the depth of winter freezing
he soil. Where the soil is lightly frozen
ing the winter and complete thawing occurs
ost simultaneously with the melting of the
w, the oxygen content is noticeably higher
in deeply frozen soil. In the ground water
he latter even hydrogen sulfide is discovered.
s difference remains for a long time and dis-
ears only as the deeply frozen soil thaws.
reasons for this phenomenon become clear
ne analyzes the data on the depth measure-
its of the standing ground water. Table 5
ws that ground waters stand on deeply
zen soil after a flood to a much greater depth
they do on slightly frozen soil, and that
difference remains for a long period. Ac-
ding to the five-year data of Golyakov (5, 6),
intake coefficient of melt water by bog soil
cultivated bog (where our experiments
e conducted) is calculated in units of the
centage of the total amount of water ac-
ulating on the bog during the spring. This
ue to excessive moisture and to impervious
in the frozen state. Apparently, in areas
re winter freezing of soil is slight and dis-
ears in the early spring, the intake coef-
ent of surface water is greater, as indi-
d by the higher ground-water level in these
s after the passage of the flood. The
nd water (vadose), fed by the surface water,
contains dissolved oxygen. The following,
uently observed phenomenon convinced us
is. In the late summer, after a severe
rain, the content of dissolved oxygen in the ground water of thawed soil proves to be higher than before the rain, the increased oxygen content is maintained for 2 or 3 days and then gradually decreases to its original value.

In connection with these data, the views of Vernadskiy (2) are interesting; namely, that "enrichment of the soil by oxygen must occur during or after a rain when it carries more oxygen in solution than is contained, as compared with nitrogen, in the air," and further, "our snow deposit is not only a winter cover, it is a vitalizing cover which in the spring yields gases more enriched in oxygen than the surrounding air."

This logical conclusion by Vernadskiy, as far as we know, has not been experimentally confirmed as yet. As our data show, it requires very great attention, especially in relation to the excessively wet and swampy soils. At the same time, the negative role of seasonal freezing for the aeration of the studied soils becomes clearer.

We have examined the changes by seasonal freezing on the temperature, nutrient and oxygen regimes of bog soils in the regions studied. Its effect on the water regime of these soils is also apparent. Interesting changes in the salt content of the studied soils associated with frozen-state phenomena are noted in recent works by Golyakov (5, 6). All this indicates that the seasonal frozen state should be taken into consideration when studying soil cultivating processes in bog soils and when carrying out reclamation and agronomic measures.

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N EXPERIMENT IN THE USE OF PHOTORESISTORS N FLAME PHOTOMETRY

N. IVANOV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Photo tubes with extrinsic photo effect and ctifiers are widely used in flame photometry. ne first are used with subsequent amplification the photo current and the second, with highly nsitive mirror galvanometers (10^{-9} - 10^{-10} np), which are not always convenient for alytical purposes.

It was interesting to investigate the possibil- y of using photoresistors -- photo electric lls with photo emission, to make a series of ıme photometry analyses. Some parameters d spectral characteristics of the photoresis- rs used in this study are given in Table 1 and Figure 1.

Table 1 shows that at the maximum permiss- le voltage, the sensitivity of the photoresis- rs amounts to 1, 2000, 000 microamperes per men. Therefore, it is not necessary to e special amplification or highly sensitive rror galvanometers.

It must be remembered that photoresistors e characterized by different temperature sponses, inertia, that the photo current and ht intensity are disproportionate, and there a direct relationship between photo current d imposed voltage.

Table 1

A few photoresistor parameters

resistor	Effective area, cm^2	Maximum operating potential, volts	Specific sensitivity, microampers per lumen and volt	Dark resistance, ohms
-K1	0. 3	400	30000	10^7 and up
-K2	0. 3	300	2500	10^6 and up
-AM	0. 21	15	5000	10^4-2 x 10^5

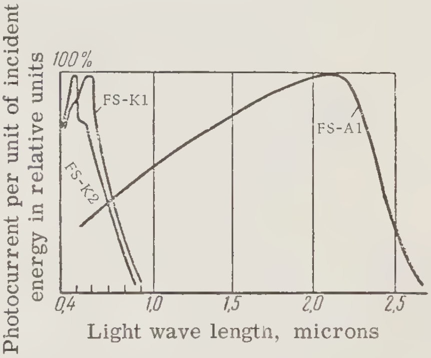

Fig. 1. Spectral characteristics of photoresistors.

In our work the elements were excited with an acetylene-air flame. Potassium, sodium, lithium, and calcium emissions were separated by interference light filters with maximum transmission in the 7680 Å, 5890 Å, and 6200 Å ranges. Filtration through the light filters was 40%-50%. The photo current was measured with an M-15 milliammeter. Solutions were fed into the flame by an atomizer and burner.[1] The principle diagram of the apparatus appears in Figure 2. Absolute sensitivity was established with pure solutions of salts of the elements.

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[1] The atomizer is constructed of "org"-glass. It is simply prepared and conveniently regulated. The diameter of the discharge orifice of the horizontal injector arm is 0. 6 mm, and that of the vertical, 0. 3 mm. Both arms are threaded. The atomizer is used in two situations; with suction and in saturated solution. In the latter case, the atomizer is turned 180° and a small cup is placed on the vertical arm. The solution to be analyzed is poured into the cup.

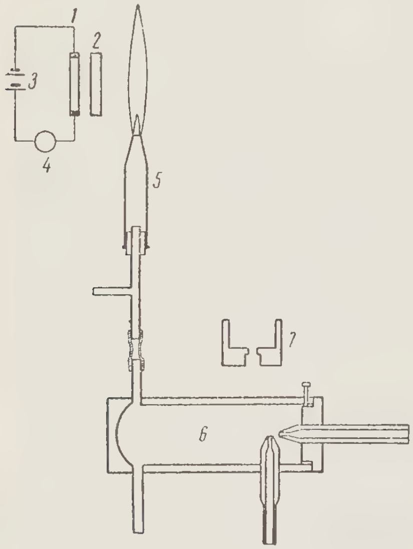

Fig. 2. - Principle circuit diagram.

1 - photoresistor; 2 - light filter; 3 - battery; 4 - milliammeter; 5 - burner; 6 - atomizer; 7 - sample cup.

With the FS-K2 photoresistor, sensitivities determined for lithium, sodium, potassium, and calcium were 0.2, 1, 2, and 10 mg/l of solution, respectively.[2] The established concentrations are adequate for the majority of soil-chemical analyses for sodium, potassium, and calcium without preliminary treatment of solutions. With the FS-K1, sensitivity was considerably less. This contradicts the above parameters and spectral characteristics. It is quite possible that herein lies the value of manufacturing the given photoresistors. Work with the FS-A1 photoresistor was impossible, since a very strong photocurrent was caused directly by the acetylene flame. This can be explained as being due to the high sensitivity of the FS-A1 in the long wave length region, the presence of intense flame emission and other filtration maxima of the interference filters. Further work was carried out with the FS-K2 photoresistor, using methods common in flame photometry (2, 3). From the known concentrations of the standards and the corresponding milliammeter readings, a standard curve was constructed according to which unknown concentrations were determined.

Comparative analyses were made using a flame photometer with a phototube, photovoltai cells, a mirror galvanometer of 10^{-10} amp sensitivity (M21/l), and the same interferenc light filters (in this case, light filters larger than 10 mm in diameter could not be used). The standard curves obtained with different flame photometers were similar. But when photoresistors are used the curvature is somewhat greater. Apparently this is due to the non-proportionality between the photo current and the light intensity. The divergence of data in determining unknown concentrations of sodium and potassium using two photometers amounted to ± 5%.

No temperature dependence was observed in the photo current. According to the literature, the photo current with the FS-K2 decreases by 1.7% in the temperature interval of 20°-40°C. Naturally, it is necessary to avoid uncontrolled, accidental heating of the photoresistor by the flame. Inertia of the photo current was noted, but this may result partly from the inertia of the registering instrument. The freedom from overloading of t photo current in voltage requires that the voltage applied to the photoresistor be constant. Under adverse conditions this may be a seriou source of analytical error.

Data obtained indicated that photoresistors may be used in flame photometry to determine a series of elements with satisfactory sensitivity and precision. Further improvements i photoresistors will increase the possibilities of flame photometry.

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[2] At the indicated concentrations, the milliammeter deflection is equal to one division on the scale.

TERMINATION OF THE WILTING COEFFICIENT BY USING E COTTON PLANT

M. KOTYSHEVA, Central Asian Scientific-Research Hydrometeorological Institute

n the system of the USSR Hydrometeorologi-
Service Administration only one method is
epted to determine the wilting coefficient of
icultural crops; namely, the use of oats as
index plant. The Main Administration of
Hydrometeorological Service and the Central
itute of Prognosis circulated this method to
administrations of the Hydrometeorological
vice as well as to the Administration of the
rometeorological Service of Central Asia.
vever, in the republics of central Asia the
n crop of the irrigated lands is cotton,
le wheat and barley are grown on the dry
ning areas.

The determination of the wilting coefficient
been of interest for a long time but up to
present, not a single suggestion has been
le concerning a change in the value of the
ing coefficient relative to the species of
t used. One group of scientists follows the
clusions arrived at by Briggs and Shantz
as early as 1912 asserted that the wilting
ficient does not depend on the plant species
on soil characteristics only. To this group
ng Karaseva (2) and Dolgova (1). Other
ntists take the position that the value of the
ing coefficient depends also on the species
ne plant used. Thus, as early as 1908, be-
the appearance of the work of Briggs and
ntz, Kostychev (3) wrote that various plants
n to wilt at different soil moistures. Ac-
ding to his data, wilting in some agricultural
ps occurs at the following soil moistures
ressed in percentages) ranging from abso-
ly dry top soil: oats, 9. 2; rye, 10. 2;
ey, 11. 1; clover, 11. 5.

n 1948, Fedorovskiy (8) conducted corre-
nding investigations and concluded that the
ing coefficient is not the same for different
ts, but depends on the plant species, its
and on the osmotic pressure of the soil
tions. Rode (4) agrees with Kostychev's
and Fedorovskiy's (8) conclusions. For
nozem soils, D. V. Fedorovskiy gives the following wilting coefficient values in relation to various plant species (in %): cucumbers, 17. 78; wheat, 15. 53; flax, 17. 97, *Salicornia* (glasswort), 16. 44; *Salsola* (saltwort), 13. 80.

Soyuz, the Union Scientific-Research Agricultural Institute, (NIKhI), in its experimental determinations of wilting coefficient for cotton follows improved methods developed by Fedorovskiy. This method is described in the work of Ryzhov and Zimina (6).

Scientists of the Uzbek Republic Hydrometeorological Service Administration have been working since 1952 to determine the agrohydrological properties of the soils in the cotton districts of the republic. They consider it expedient to use cotton plants as indicators for wilting coefficient determination. However, considering the fact that there are various opinions concerning the selection of an indicator, the Boz-Su (Tashkent) Agro-meteorological Station in 1956 made a special study of the relative standing of wilting coefficient values obtained for cotton by the Union NIKhI method and for oats by the Central Institute (TsIPa) method (5).

Determinations of the wilting coefficients for these plants were carried out on typical sierozems (fine clay loams). Soil samples were taken from an irrigated section planted to cotton. The pot experiment was set up according to the Union NIKhI method as follows: air-dry soil was put into tea glasses (200 cm^3 capacity) until they were three-quarters full. The soil was tamped by light tapping of the glass against the edge of the table. Then a layer of sand was placed on the top and through it the soil was moistened to full moisture capacity. Mineral supplements of 0. 2 g of nitrogen and 0. 2 g of phosphoric acid per kilogram of soil were added to the soil in the glasses. Four to five germinated cotton seeds were transplanted in the sand. After the appearance of the cotyledenous leaves the plants were thinned leaving only two plants per glass. The determination was replicated three times for each of the soil samples taken from 10 cm soil depths (0-10; 11-20; 21-30; etc., to 91-100 cm).

The wilting coefficient was determined in two ways: 1) one group of glasses was placed on a table around a marked area and was shielded from direct sun rays by gauze shades; 2) the other glasses were placed on the north side of the agricultural-meteorological station building so that no direct sun rays would fall on them (method used by CIPa to determine the wilting coefficient of grains).

In both techniques, the cotton was irrigated twice daily until the appearance of the fourth permanent leaf after which the glasses with cotton plants were sealed. The normal wilting of the cotton plant was assumed to be the condition in which the plant lost its turgidity and did not recover when placed in a humid atmosphere. When the cotton plants of the first group wilted they were 8-9 cm high, those of the second group were 11-12 cm high. The cotyledenous leaves of the majority of plants in the first group curled and dropped off in some cases. The remaining leaves were green. The root system was well developed and completely permeated the soil.

From the time the first cotton shoots appeared until they wilted, an average of 17-26 days passed. In the second experimental group all leaves were green and no leaves dropped off. Root system was also well developed. The number of days between the appearance of shoots until they wilted varied between 19 and 24.

Under the conditions of the experiment, air temperature was measured twice daily (morning and day) among the cotton pots with a small model aspirating psychrometer. In the morning hours (8 o'clock) air temperature of the first experimental group varied between 24° C and 28° C on the dry thermometer and in the second group, between 21° C and 26° C. During the day (13 hours) the corresponding temperature was 30° C-37° C and 29° C-35° C.

Using the same soil, an experiment was set up with oats, using the TSIPa method which is briefly described. The soil (average sample) was placed in glass containers 10. 8 cm high and 2. 5 cm in diameter. The soil was lightly packed and moistened until completely soaked. A single, germinated oat seed was placed in each of the glasses. The experiment was replicated four times for each 10 cm of the soil sample. After growth was observed, the soil surface was sealed. The containers were placed on the north side of the building along with the cotton plants of the second group. Wilting in oats was observed after turgidity was lost from the leaves. It should be observed that at the moment of wilting the leaves darkened and curled slightly. The root system was well developed and reached the bottom of the glas The air temperatures corresponded to those given for the second cotton group. Results c our determinations are given in Table 1.

Studying the wilting coefficient values for cotton depending on the location of the pots, we can see that in both groups these values a close to each other. Differences in the coefficient values occurring at different depths varied between 0. 0% and 0. 5%. The wilting coefficient of cotton is 0. 7%-1. 9% higher tha that of oats at the various soil layers.

To check the accuracy of the results obtained the data were analyzed mathematicall All replicates for each depth were compared pairs and a mean error was determined by t method of small selections (7). As a result of this analysis, of which a total of 30 determinations were made, an average value for the wilting coefficient was obtained: cotton, 6. 3; oats, 5. 3, the average difference betwe the two being ±1. 0%. The average error is m ±0. 3% with difference of 3. 3° C temperatu and humidity <0. 01. This provides a basis f the belief that the actual differences between the wilting coefficients of cotton and oats we obtained in our investigations.

To study the practical application of the wilting coefficients obtained, productive moi ture storage in the soil were put into typical sierozems, using the same coefficients dete mined for both cotton and oats. Results obtained are given in Table 2.

From Table 2 we note that the productive moisture storage in the second 10 days of A determined by the wilting coefficients of cott and oats, are not identical. Using the oat w ing coefficient, results in higher indications productive moisture in the 1 m layer (in 15. mm), the arable layer (at 3. 9 m) and the 10 layer (1. 5 mm). This last is especially ess tial in the spring period when cotton is being sown and the appearance of its shoots is awa

From data available at the NIKhI and at t Boz-Su Argo-meterorological Station it can seen that retention of 10 mm of productive n ture in a 10 cm layer of soil is the limit at which cotton shoots appear. However, if we account for these 10 mm of productive moisture on the basis of the oat-wilting coefficie then, for cotton, it will actually be 10-2 mm (rounded off) -- 8 mm (according to data in Table 2), which does not assure the appeara of cotton sprouts.

From this we can deduce that on typical Uzbekistan sierozems -- primarily under irrigation -- on which cotton is planted, the

Table 1

Wilting coefficient for cotton and oats in percentages of an absolutely dry portion of typical sierozems

Stations and soil	Depths, cm	Cotton		Oats	Difference in data
		In the sun	In the shade		For cotton and oats
Boz-Su	0—10	6,8	6,5	5,4	+1,1
(Tashkent)	11—20	6,9	7,1	6,1	+1,0
Typical	21—30	6,9	6,9	6,2	+0,7
sierozem	31—40	6,3	6,6	4,7	+1,9
Fine clay	41—50	5,9	5,9	5,1	+0,8
loam	51—60	5,6	6,0	5,2	+0,8
	61—70	6,3	6,6	5,8	+0,8
	71—80	5,7	5,9	5,1	+0,8
	81—90	6,0	6,0	4,8	+1,2
	91—100	5,4	5,9	4,2	+1,7

Note: Comma represents decimal point.

Table 2

Productive moisture storage according to Boz-Su Station data for typical sierozems, mm

Date	Depth, cm	Cotton	Oats	Variation in productive moisture storage between cotton and oats
		In the shade		
1956 April	0—10	18. 6	20. 1	—1. 5
	0—30	53. 2	57. 1	—3. 9
Second 10 days	0—100	196. 8	212. 2	—15. 4

ing coefficient should be determined with
on as an indicator, and not with oats.

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DETERMINING CARBON DIOXIDE AND OXYGEN CONTENT IN SOIL AIR[1]

B. N. MAKAROV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The determination of the carbon dioxide and oxygen content in soil air is of great interest for soil, chemical, and physiological studies. These determinations characterize the intensity and trend of the biochemical processes in soil, and the conditions required for the growth of plants.

Soil air is usually sampled either by setting up stationary tubings at a specific depth (5, 4) or by needle-probe (1, 3, 8). The carbon dioxide and oxygen content is determined mostly by gas analyzers (Gol'dana, Orsa, VTI-1, etc.). To determine CO_2 and O_2 concentration by gas analyzers requires a cumbersome apparatus and a great amount of time. To simplify the methods for determining CO_2 and O_2 in soil air we have proposed using round-bottomed flasks with a 150-250 ml capacity and ground glass stoppers (Figure 1). A glass tubing with a stopcock (Figure 1, a) and a tube b into which is inserted a ground glass tubing c and a stopcock are tightly sealed into the stopper. The tubing extends as far as the bottom of the flask.

Soil air is sampled in the following manner. The flask is completely filled with distilled water, the inserted glass tubing is connected by a rubber tubing to the probe for sampling the soil air or to a brass tubing set in the ground (Figure 2). Stopcock 1 is opened, then stopcock 2. In order to charge the probe-rubber tubing system with soil air, 20-40 ml of water is let out of the flask, and, then, the flask is again filled with water. The stopcocks are opened, the water flows out of the flask, with the soil air entering the flask. When all of the water has been released from the flask, stopcocks 1 and 2 are closed. The concentrations of carbon dioxide and oxygen are determined separately, for which two samples are taken, one for determining CO_2, the other fo determining O_2.

Determining the CO_2 Concentration

When the soil air has been sampled, the flask is disconnected from the needle-probe or brass tubing. The inserted tubing (Figur 1c) is removed and 10-50 ml of barium oxid (depending on the content of CO_2) is quickly pipetted into the flask and the tube opening i sealed with a rubber tubing. To absorb the CO_2, the barium oxide in the flask is violent shaken for 3-5 minutes, and, then, the exce barium oxide is titrated back by a phenolpht lein indicator with 0.02 N HCl solution. Fr the difference between the free titration of 10-50 ml of barium oxide and the titration o the same amount of barium oxide after abso ing CO_2 we can determine the content of car dioxide in a volume of soil air which corresponds to the size of the flask, by taking int account the given amount of barium oxide (1 50 ml). Computing is done in mg/l or, in volume percents, by reduction to normal co ditions (t° = O, pressure = 760 mm).

The CO_2 content in soil air was determin by the foregoing method for the peat-bog an podzolic soils. The differences among repe withdrawals from the same spot was not mo than 10%, (Table 1), which indicates an exce lent agreement among the parallel determin tions. These data show that it is entirely possible to withdraw two soil air samples o 150-250 ml from one spot (one for determin the CO_2 content, the other for determining

The question might arise as to whether t CO_2 is absorbed by water when a sample of soil air is drawn off. To show what happen we have sampled from one spot by filling th flask with water, on one case, and with a sa urated solution of NaCl, in another.

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[1] M. A. Shvabe participated in field and laboratory studies.

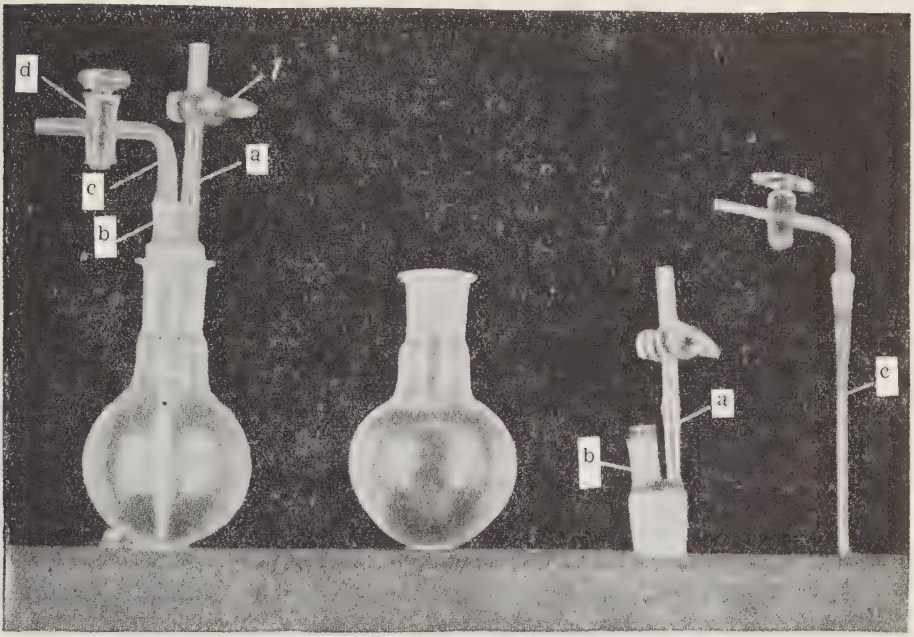

Fig. 1. - Flasks for withdrawing a sample of soil air and for determining CO_2 and O_2.

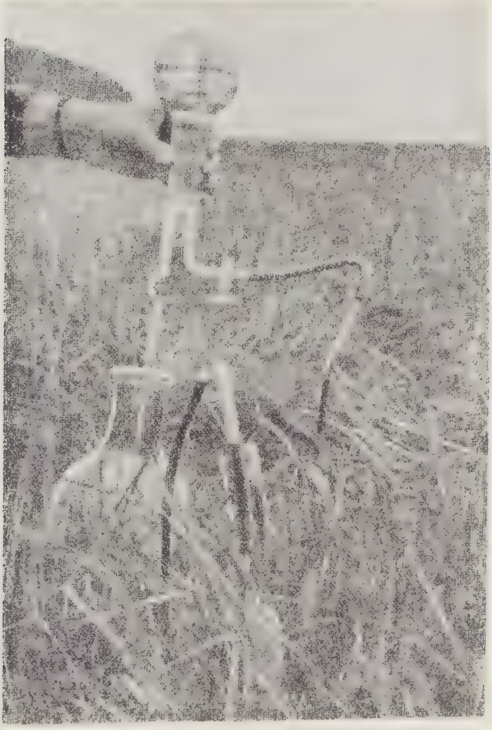

Fig. 2. - Withdrawing soil air from a brass tubing.

Table 1

Differences among parallel determinations in withdrawing soil air from one spot

Date of determination	CO$_2$ content in volume percents at depths of					
	10 cm		20 cm		30 cm	
June 5	0. 270	0. 288	0. 530	0. 520	—	—
June 12	0. 985	0. 920	2. 14	2. 22	3. 13	3. 02
June 13	0. 730	0. 700	3. 18	2. 98	7. 30	6. 85
June 27	0. 540	0. 530	2. 50	2. 45	—	—
July 9	1. 34	1. 47	1. 76	1. 77	2. 40	2. 73
July 10	0. 558	0. 532	1. 78	1. 60	4. 92	4. 22
July 17	0. 722	0. 665	1. 70	1. 74	2. 81	2. 96
July 19	—	—	1. 45	1. 47	2. 06	1. 97
July 19	1. 11	1.08	1. 65	1. 60	2. 66	2. 52
July 25	—	—	1. 79	1. 88	3. 14	3. 14
	—	—	1. 47	1. 44	2. 17	2. 19

Table 2

Comparing the results of CO$_2$ determinations in volume percents with the flask filled with water and salt

Date of determination	Depth, cm	20		30	
	Soil	Water	Salt	Water	Salt
June 19	Sod-podzolic	0. 237	0. 197	0. 376	0. 392
July 4	Peat-bog	2. 11	1. 80	2. 70	2. 72
July 25	" "	1. 92	1. 76	2. 57	2. 48
		1. 39	1. 45	2. 04	2. 18
		1. 20	1. 22	1. 90	1. 72

Table 3

Comparing the two methods for determining CO$_2$ concentration in soil air expressed in volume percents

Plot	Depth of soil air sample, cm	Gas analyzer	Flasks	Difference between the two methods in %
Grass-woody peat	10	1. 21	1. 17	-3
	20	2. 15	2. 09	-3
	30	3. 09	3. 05	-1
	60	5. 42	6. 49	+19
	30	1. 20	1. 20	0. 0
	60	1. 85	2. 06	+12
Grassy-hypnum peat	10	1. 69	1. 50	-11
	10	2. 20	2. 00	-9
	20	3. 62	2. 99	-17
	30	8. 52	10. 0	+15

)ne determination of the CO_2 concentration oil air, directly conducted in the field, took than 5 minutes (since we could shake eral flasks at one time).

Determining the Oxygen Concentration

'o determine the O_2 concentration in soil we used the Vinkler (6) method, which been worked out for determining the oxygen ent in water. This method was based on oxidation in the alkaline medium of Mn^{+2} In^{+3} and Mn^{+4}, the latter in an acid medium izing the iodine ions to a free iodine. The rated iodine is titrated back by hypsosul- e. By this method Khlopin (7) determined concentration of oxygen in air. To do this, sed concentrated solutions (40% MnCl and alkaline solution Kl). The oxygen was pletely absorbed in his experiments after hours. To accelerate the rate of deter- ing oxygen in air, we conducted a series of ies on the determination of the required ber and concentration of reagents. It was en that oxygen is absorbed more quickly completely when weak solutions are used.

Fifteen ml of an alkaline solution of KI and 40 ml of a 7% solution of $MnSO_4$ are used for flasks with a 150-200 ml capacity; for flasks with a 200-250 ml capacity, 20 and 60 ml of the foregoing solutions, respectively, are used.

Table 4

Difference among the parallel determinations of the oxygen content in atmospheric air expressed in volume percents

Date of determinations	1	2	3	4	Mean
January 29	21. 0	21. 2	—	—	21. 10
January 31	21. 1	21. 2	—	—	21. 15
February 1	21. 0	20. 9	20. 1	21. 3	21. 05
February 3	20. 8	21. 1	21. 1	20. 8	20. 92
February 6	21. 0	20. 9	20. 7	—	20. 87
February 7	21. 2	21. 2	21. 0	21. 0	21. 00
February 8	21. 0	21. 0	21. 2	—	21. 06

ıod of Analysis

fter a soil air sample, 15-20 ml of alkaline :ion Kl and 40-60 ml of manganese sulfate ıanganous chloride are pipetted into the through the tubing (for lowering the sur- tension and accelerating the reaction we add 1-2 drops of isoamyl alcohol); the opening is sealed by a rubber stopper. To rb the oxygen the contents of the flask are ntly agitated for 20-25 minutes; during time the color of the liquid changes from to brown, then becoming dark-brown, st black, without changing any further ıg subsequent agitation. Twenty to twenty-five ml of concentrated HCl or H_2SO_4 (1:1) are quickly pipetted into the flask. The contents of the flask are shaken; at the same time the iodine which is titrated back by 0. 1 N solution of sodium hypsosulphite is separated. After titration 2 ml of starch is added as a indicator; 1 ml of a 0. 1 N solution of hypsosulphite = 0. 56 ml of oxygen at O° and 760 mm. The O_2 concentration is found from the following formula:

$$\frac{A \times K \times 0.56 \times 100 \times 760(273+t^\circ)}{({}^{V}K-{}^{V}p)(W-w)\times 273} = \text{volume percent of } O_2$$

where A = number ml 0. 1 N $Na_2S_2O_3$ with a correction K; ${}^{V}K$ = volume of the flask in ml; ${}^{V}p$ = volume of given solutions in ml (15 ml of alkaline solution KI and 40 ml of $MnSO_4$); t° and W are temperature in C. and air pressure; w is water vapor pressure at t°.

The needed reagents are:

1) An alkaline solution KJ 160g NaOH and 150g KJ dissolved in 1 liter of boiled distilled water. 2) 7% solution of $MnSO_4$, SH_2O or $MnCl_2 \times 4H_2O$. 3) Acid: HCl (concentrated) or H_2SO_4 (1:1). 4) Hypsosulphite 0.1 N solution (25 g per 1 liter). 5) 0.5% solution of starch.

To check the similarity among the parallel determinations we conducted a series of determinations of the oxygen content in atmospheric air by using the proposed method. (Table 4).

As is evident from the data shown in Table 2, when the flask was filled with water, we obtained the same or somewhat better results than when the flask was filled with a saturated solution of sodium chloride, all of which indicates an almost complete absence of a CO_2 solution in the water during the withdrawal. The absence of CO_2 absorption by water during withdrawal is explained by the fact that a sample of soil air is withdrawn only for 40-60 seconds and that the air at the same time is not being mixed with water. As Gorbunov's (2) experiments have shown, CO_2 is noticeably dissolved in water whenever air is passed through the water for one hour.

To compare the results obtained when using the proposed method and the gas analyzer method, we sampled soil air from the same brass tubings in various sections and conducted simultaneous determinations using these two methods, i. e. the flask and gas analyzer method.[2]

As is evident from the data indicated in Table 3, the results of the determinations by these two methods are almost the same; in three cases the differences amounted to 15%-19%.

As is evident from the data, the differences among the parallel determinations are small.

When working with flasks we must see to it that the stopper and stopcocks are well ground to avoid atmospheric air from entering. The size of the flasks and the amounts of introduced reagents should be measured exactly.

CONCLUSIONS

A simple method for determining oxygen and carbon dioxide in soil air by flasks with ground glass stoppers has been proposed. Withdrawal of soil air and determining the CO_2 and O_2 concentration were carried out directly in the field using the same flasks. Carbon dioxide was absorbed by barium oxide. The determination of oxygen was based on the oxidation in the alkaline medium of a divalent manganes into a tri- and tetravalent manganese, which in the acid medium oxidizes the iodine ions to a free iodine, (which is titrated back by hypso sulphite).

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[2] Determinations by the Gol'dana gas analyzer were made by V. B. Matskevich, to whom I am deeply thankful.

ETERMINATION OF MAXIMUM HYGROSCOPICITY
DR CLAY LOAM SOILS

M. CHERNOUKHOV AND A. V. NUZHDIN, Voronezh Agricultural Institute

Maximum hygroscopicity is used to estimate nt wilting moisture. This knowledge is cessary to the agronomical evaluation of soil l to estimate the values for irrigational and inage norms in an artificially regulated ter regime. It is determined (1, 2) by the uration of suspension of air-dried soil to a nstant weight above 10% sulphuric acid (after tcherlich) or above a saturated solution of assium sulfate (after Nikolaev). The saturan process takes from 1. 5-2. 0 months. Soil nples are very accurately weighed every ee to four days.

Analysis of the quantitative change in moise which occurs during the saturation of aired samples from various horizons of the ive soil layer (up to 1. 0 m), given in Table 1, icates that it is possible to greatly simplify method of maximum hygroscopicity deternation, a very important matter in major dies.

Table 1 shows that the moisture (G) of aired samples taken from different horizons to 1 m) increases during saturation to an nost identical value (P). This allows us to uce the technique to the following:

1. Selection of samples and treatment until air-dry. 2. Determination of the moisture in the air-dried samples (G%). 3. Determination of maximum hygroscopicity for two to three samples using either the Mitcherlich or the Nikolayev method. 4. Determination of the average index P = MG - G%. 5. Calculation of maximum hygroscopicity for the remaining samples Mg = G + Psr%. This method decreases the loss of reagents and time in the frequent and accurate weighing of a large number of samples, and yet, as can be seen from the table, its results are sufficiently accurate.

Since we have experimental data for one soil group only it would be fruitless to state that a similar picture will result in all of the cases. The possibility for simplified calculation of maximum hygroscopicity in relation to other soils requires practical testing.

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Table 1

Maximum hygroscopicity of ordinary chernozem
on a loess-like carbonate clay loam
(Voronezh, students of the Agricultural Institute "party," 1954-1956)

Test No.	Depth, cm	Moisture in air-dried sample (G)	Maximum hygroscopicity (MG)	Increase in moisture for saturation (MG-G) = P, %	Average increase (P_{sr}), %	G-P_{sr}, %
		% of weight of absolutely dry soil				
1	0-10	7.13	10.73	3.60	3.64	10.77
	10-20	7.30	10.95	3.65		10.94
	20-30	7.99	11.64	3.65		11.68
	30-40	7.89	11.42	3.53		11.53
	40-50	7.24	11.15	3.91		10.88
	50-60	7.27	11.01	3.74		10.91
	60-80	6.13	9.81	3.68		9.77
	80-100	4.80	8.10	3.30		8.44
2	0-10	4.00	8.43	4.43	4.43	8.43
	10-20	4.03	8.37	4.34		8.46
	20-30	4.16	8.77	4.61		8.59
	30-40	4.19	8.78	4.59		8.62
	40-50	3.92	8.36	4.44		8.35
	50-60	4.12	8.59	4.47		8.55
	60-80	3.86	8.28	4.42		8.29
	80-100	3.71	7.84	4.13		8.14
3	0-10	4.99	8.73	3.74	3.68	8.67
	10-20	5.07	8.80	3.73		8.75
	20-30	5.59	9.38	3.79		9.27
	30-40	5.45	9.30	3.85		9.13
	40-50	5.43	9.00	3.57		9.11
	50-60	5.42	9.04	3.62		9.10
	60-80	4.80	8.49	3.69		8.48
	80-100	5.02	8.45	3.43		8.70

OSSIL SOILS OF THE AZOV SEA COAST

P. BULAVIN, Planning Institute, Moscow

Horizons of dark-colored, humus-like clay ms, known as fossil soils or fossil humus izons, are widespread throughout the blan- loess formations in European USSR. Sev- l such horizons, deposited in layers, usually ur in the same profile.

Several original hypotheses have been pro- ed to explain the origin of these loess hori- s, but at present the prevailing opinion is t they were deposited in areas remote from h other by different geological agents and t they are related in some way to continental mountain glaciation. In western Europe ere the loess gravitated toward the river leys the process was primarily alluvial. In opean USSR, where a continuous loess nket developed, on the watersheds, the de- ive role was played by undeveloped outwash lacial streams. Proluvial and diluvial cesses were in operation in a similar man- in central Asia. At present, the eolian othesis offers the best explanation for the gin of the thick Chinese loess. Advocates of fluvio-glacial hypothesis call the fossil nus horizons snow and ice deposits, rich in anic matter (2), and those who favor the lian hypothesis assume them to be buried tinental deposits originating during several er-glacial periods (3).

A series of loess outcrops of broad extent, wn to exist on the shores of the Azov Sea, e attracted the attention of geologists in the t. These outcrops enabled geologists to ce detailed studies of the deposition condi- s of the humus horizons. We shall briefly cribe the evolution of this factual data and t conclusions can be drawn from it.

The first studies of the northwestern coastal a between Molochnyy estuary and Berdyansk e made by N. A. Sokolov in 1888. His re- s showed that the coastal cliffs of the loess eau between Molochnyy estuary and Obi- naya spit were composed mainly of reddish- wn and yellowish-brown clay with occasional rstratified greenish clay below, while the fs between the Obitochnaya and Berdyan- ya spits were grayish and yellowish sand below and yellowish-brown clay above (6). However, Sokolov's book contains no description of the humus horizons and we must assume that they apparently went unnoticed.

In contrast, Lisitsyn (4), describing in 1914 the loess formation in the deep railroad cuts between Novocherkassk and Rostov stated that in the clay loam covering the watersheds "stratification is not visible, generally, but it is possible to determine the nature of its structure from the interstratified darker humus layers, which usually exactly parallel each other over a great distance and which run in approximately a straight line, coinciding with the local topography."

In 1953 we retraced N. A. Sokolov's route along the shore of the Azov Sea from Molochnyy estuary to Osipenko (formerly Berdyansk). We not only observed the presence of several buried humus horizons in the local loess layer but also the same conditions of deposition which K. I. Lisityn described in the Novocherkassk and Rostov region. In the broad expanse of the northwestern part of the sea coast where the highly eroded shores between Molochnyy estuary and Obitochnaya spit make an almost continuous line of excellent, constantly renewed outcrops, it was discovered that three to four dark-colored, almost horizontal and parallel humus horizons are interstratified with the brown loess clay loams with almost complete geometric monotony. Similar characteristics, easily observed by studying the outcrops, were described by us at Osipenko as well as in the Genichesk region (Fig. 1). At the latter a clearly defined stratified structure, noteworthy because of a horizon of large carbonate concretions, occurs in the underlying clays (Fig. 2).

The strict parallelism in the deposition of the series of humus horizons was the most important factor in K. I. Lisitsyn's and, consequently, in our observations. Such relationships contradict the multiglacial theory for fossil soils and buried, continental surfaces of several separate interglacial periods. If the latter were the case, then each humus horizon, in turn, would have a clearly expressed inde-

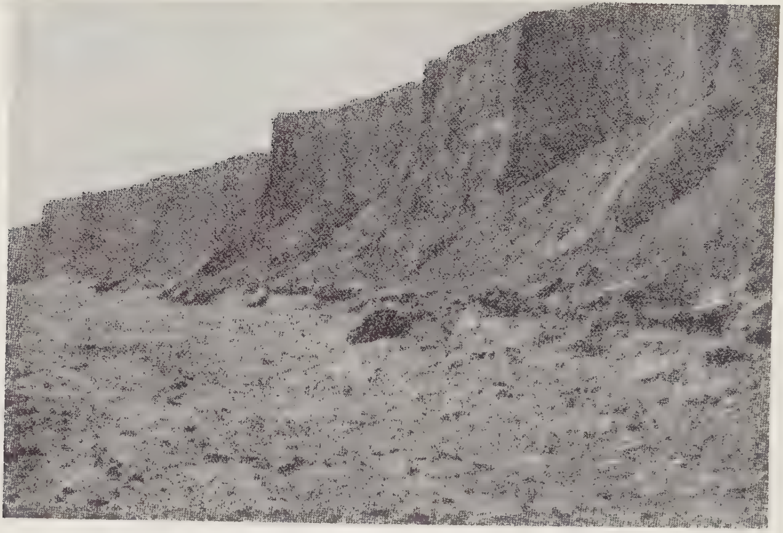

Fig. 1. - Stratified structure of the loess at Genichesk.

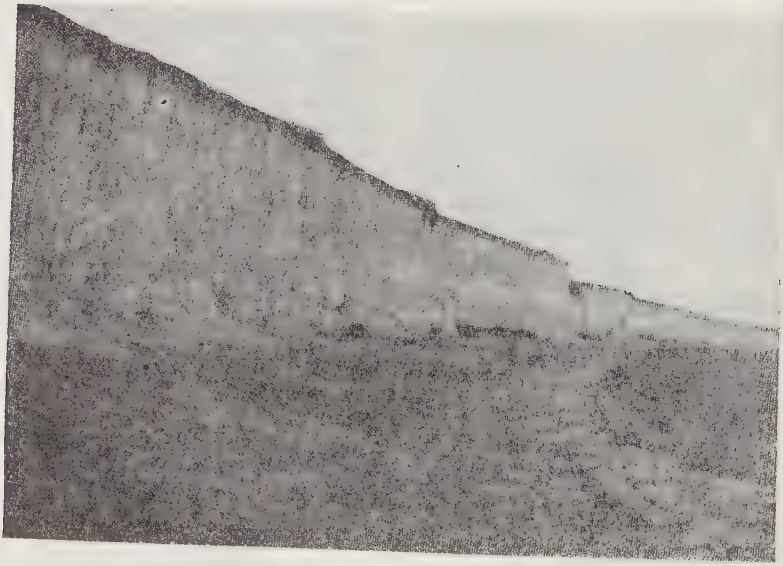

Fig. 2. - Stratified structure of the underlying clays in the Genichesk region.

endence of stratification, and the layers of uch a series would not parallel each other. nstead, ancient hills, slopes, and gullies vould appear in the layers.

Therefore, we are inclined to consider all ossil horizons found in the outcrops in the rea around the Azov Sea to be formations elonging to a single glacial period indicating nly intervals of short duration when glacial vaters deposited a layer of distinctive loess ine earths. This point of view agrees with vhat is known as the mono-glacial idea.

It seems strange that the morphologic char- cter of the humus horizons, discovered earlier y K. I. Lisitsyn and verified by us, was not etected by those studying the Taganrog loess 1, 5). The comparatively small exposure of he local outcrops was, perhaps, the reason. Iowever, because the nature of the deposition f the humus horizons on the coast of the Azóv ea is not clear, subjective interpretation irectly related to polyglaciation relates to the roblem of the stratigraphy of the entire loess ormation of a given region as well.

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LIME CONCRETIONS IN SEMIDESERT SOILS

N. KULIK, Achikulak Laboratory of Organic Synthesis

Large areas of exposed sands are found in the semidesert zone of the Northern Caucasus and, particularly, on the right bank of the Astrakhanskaya Oblast'. They are composed of barchane chains, alternating with bare weathering basins whose bottoms are extremely solid (compact, hard) and covered with many lime concretions (nodules, as T. F. Yakubov calls them), up to the size of a large pea. The assumption is that these concretions are soil formations. After the basic cover has been blown away, the more stable concretions remain in tact and assume a rolled shape as a result of wind action.

Actually the concretions are so hard that we cannot crush them by hand; they are whitish-colored (which makes them somewhat similar to white flecks) but the nature of most of them is in no way associated with the soil-forming processes. Hot climate, calcium salt and the presence of hard solid fragments devoid of vegetation are responsible for these concretions. These conditions are found in the semidesert regions of the Caspian Sea.

During the summer days the surface of the Astrakhanskaya sands is heated to 70-75°C and a certain portion of the calcium carbonate is broken up by the formation of calcium oxide (CaO). This process takes place more actively on sands unprotected by vegetation, including sands found at the bottoms of weathering basins. The wind which intensifies the blown-off carbonates also contributes to this process. The lime burned in original natural furnaces is mixed with silt and redistributed by the wind over vast areas.

The formation of concretions from such a "building material" takes place when it rains and only when the rain falls as extremely rare large drops on a hard bare surface. Owing to the hysteresis of the wetting process the rain drop may not be absorbed at once into the soil, but may, somewhat later, when covered by silt, roll across the hard bottom of the weathering basin. The same phenomenon can be seen on dusty, overheated asphalt, when it begins to rain.

The calcium oxide, mixed on the whole, with mineral silt, is united with rain water, forming calcium hydroxide $Ca(OH)_2$. A small chunk basically consisting of lime mortar gradually hardens. The calcium hydroxide adds carbon dioxide from the air, loses the water and is transformed into calcium carbonate. The small chunk becomes very stable (hard). The fact that silt particles along with an enormous connecting surface enter into its composition also contributes to this process.

We can form lime concretions by artificial means. To do this, we must completely clean a bare section of a hard-bottomed weathering basin and then leave it standing for 2-3 weeks. Then, we must sprinkle the section with water, which shall result in the formation of very hard (stable) chunks.

The lime concretions, buried by a layer of reshifting sand, may lead to inaccuracies in describing the soil. The bottom of these basins is assumed to be an illuvial horizon with a concentration of carbonates. This may actually be a cemented parent rock material with lime concretions of surface origin.

The exceptionally great stability of the formations described previously and their round shape are the basic differences between these formations and the carbonate nodules of soil origin (which are also numerous at the bottoms of the basins).

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REVIEW

HE PHYSICS AND COLLOIDS OF SOILS

Di GLERIA, A. KLIMES-SZMIK AND M. DVORACSEK, Hungarian Academy of Sciences,
udapest

This 728 page book has nine parts, each of
ich has three to nine chapters. It includes
list of 538 references, a considerable num-
r by Soviet authors, and author and subject
dexes, as well as many tables, graphs and
her illustrations. A characteristic feature is
e inclusion in the text of descriptions of the
ain points of research methods. The book is
signed for scientific workers and instructors
the higher institutions of learning, aspirants
d students specializing in agricultural chem-
try and soil science.

The first part of the book gives an account
contemporary ideas on the inter-action of
olecules and ions in water and water solutions,
well as in solids. Concepts on colloidal
stems and the conditions for their stability
e introduced.

The second part discusses inorganic, or-
nic and organo-mineral soil constituents,
eir composition and properties.

The third part deals with physico-chemical
d colloidal soil properties (the phenomenon
adsorption, soil reaction and acidity), using
em to explain soil-forming processes and
ant nutrition.

Physical and mechanical soil properties are
scribed in the fourth part of the book (soil
xture, aggregation, plasticity, swelling,
rinkage and moisture properties of soils are
eated here).

The fifth part discusses problems of soil
xture and structure (form of aggregates,
nesis, cementing substances, etc.).

The sixth part of the book deals especially
th soil moisture (its forms, and the forces
taining water in the soil), and the seventh
rt with a detailed study of soil air.

The eighth part deals with problems of heat
enomena in the soil.

In the ninth part an account is given of the
rt played by various agricultural and meliora-
n measures (soil cultivation, irrigation, drainage) in improving the physical properties of soil. Examples are drawn from Hungarian agricultural practice.

The chief merits of the book are: 1) description of original methods of soil investigation, among them rapid methods such as Prof. Aranya's method for determining soil bonding and indirectly, texture; this method is widely used in Hungary; 2) the inclusion of a large amount of data on the determination of physical and colloidal properties of the main Hungarian soil groups, making it possible to compare the properties of various soils; 3) the theoretical viewpoints and conclusions in the book are illustrated by data showing the possibility for practical recommendations for agriculture. For instance, in the third chapter, in the section dealing with factors affecting the availability of soil nutrients to plants, theory is directly related to fertilizer practice; in the fifth chapter problems of soil structure are accompanied by a description of methods for soil improvement; in particular, the problem of synthetic soil structure-forming agents for irrigated and non-irrigated Hungarian soils is considered from many angles. Besides testing foreign preparations the authors have made a thorough study of the Hungarian polyacrylate compound known as 'polnakrilat-solokrol'.

A strong feature of the book is the pedologic-genetic approach to the characterization of the main Hungarian soils according to their physical and colloidal chemical properties. This enables the reader to make extensive use of these data for comparison with similar data for soils of other countries. A special section gives characteristics of irrigated soils according to their physical properties.

The book is successfully used in Hungary both by scientific workers and students and by specialists in all branches of agriculture. The book is up to present-day scientific standards.

Reviewed by I. N. Antipov-Karatayev and
I. Sabol'ch

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